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# Three Essays on Economic Analysis of Production Systems of U.S. Grass-fed Beef Industry

Basu Deb Bhandari
*Louisiana State University and Agricultural and Mechanical College*, bgbhandari@gmail.com

# THREE ESSAYS ON ECONOMIC ANALYSIS OF PRODUCTION SYSTEMS OF U.S. GRASS-FED BEEF INDUSTRY

A Dissertation

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by
Basu Deb Bhandari
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Dedicated to my late parents (Late father Mr. Dadiram Bhandari and Late mother Mrs. Nanda Kala Bhandari)

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# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# ABSTRACT

This dissertation research consists of three essays. The first two studies analyze experimental research data based on three pasture systems for grass-fed beef (GFB) production in the Gulf Coast Region. System 1 included bermudagrass and ryegrass; System 2 included bermudagrass, ryegrass, rye, dallisgrass, and clover mixtures (red, white, and berseem clovers); and System 3 included bermudagrass, soybean, sorghum sudan hybrid, ryegrass, rye, dallisgrass, and clover mixtures (red, white, and berseem clovers). Fifty-four Fall-born steers were weaned in May and grouped into nine groups and randomly blocked into treatments and replicates. Inputs and output data were recorded on a daily basis. Greenhouse gas (GHG) emissions in terms of $CO_2$ equivalent emissions from each system were estimated based on the experimental data and literature for the first three years (2009/10 to 2011/12). For the first essay, the three pasture systems were analyzed to maximize the profitability and sustainability of grass-fed beef production. The simplest grazing system yielded higher profit than the most complex, but the most complex system produced the lowest greenhouse gas impact. A trade-off was found between profitability and GHG impact among the systems. In the second essay, the same three pasture systems were analyzed for labor use and profitability based on five years of experimental data (2009/10 to 2011/12). System 1 was more profitable as well as more labor consuming. Systems 1 and 2 were more profitable than System 3 with or without including the labor expenses. Application of simulation and dominance techniques showed that decision makers would choose between Systems 1 and 2 based on their risk preferences.

The third essay analyzes the technical efficiency of grass-fed beef farms in the U.S. The study is based on a cost and return survey conducted in 2013. The average technical efficiency of

grass-fed beef production was found to be 76%. Technical efficiency is positively affected by farm specialization, and percentage share of grass-fed beef meat in GFB income and negatively impacted by off-farm income and owning cow-calf segment. Increasing return to scale was found in GFB production and larger-scale farms were found to have lower average costs than smaller-scale farms.

# CHAPTER 1: INTRODUCTION

## 1.1. Overview of Grass-fed Beef Production in the U.S.

A wide range of forage systems can be used to produce grass-fed beef (GFB), with each system resulting in potentially different productivity, profitability and sustainability outcomes. Grass-fed beef refers to beef from cattle whose lifetime diet consists of only grass and other forages, with the exception of milk consumed prior to weaning; no grains are fed. This definition is the USDA definition of GFB (USDA, AMS, 2007). Various terminologies are used to describe GFB like pasture-fed, grass-fed, grass-finished, forage-fed, and forage-finished. The term GFB is used throughout this dissertation. Although GFB preceded grain-fed beef production as a practice of raising cattle, grain supplementation has been standard practice in U.S. cattle production since the 1950s (Schupp et al., 1979).

The U.S. beef industry is the second largest U.S. agricultural industry and is the largest fed-cattle industry in the world. As per USDA's projections (USDA, 2014), overall beef production is forecast to increase slightly through 2020 after a relatively constant trend with recent decreased production over the last 15 years (Figure 1.1). The relatively small changes over the period have been mostly due to changing prices of grains and other feeds as well as prices of competing meats. Over this period, GFB production has experienced increased consumer and producer interest due to its nutritional value, animal welfare and sustainability issues. With increased interest by producers and consumers for GFB production systems, both USDA and the American Grass-fed Association (AGA) provided definitions for GFB, albeit with subtle differences in the definitions.

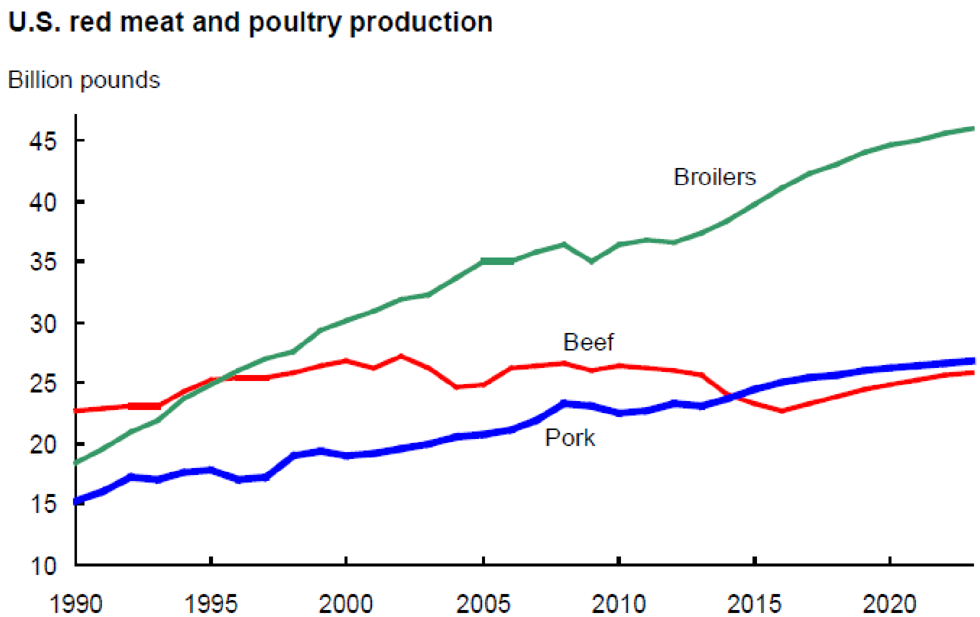


Figure 1.1. U.S. Red Meat and Poultry Production
Data Source: USDA Agricultural Projections, February, 2014. Long-term Projections to 2023

USDA, AMS (2007) defined the grass fed claim and standard as: “Grass and forage shall be the feed source consumed for the lifetime of the ruminant animal, with the exception of milk consumed prior to weaning. The diet shall be derived solely from forage consisting of grass (annual and perennial), forbs (e.g., legumes, *Brassica*), browse, or cereal grain crops in the vegetative (pre-grain) state. Animals cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season. Hay, haylage, baleage, silage, crop residue without grain, and other roughage sources may also be included as acceptable feed sources. Routine mineral and vitamin supplementation may also be included in the feeding regimen. If incidental supplementation occurs due to inadvertent exposure to non-forage feedstuffs or to ensure the animal’s well-being at all times during adverse environmental or physical conditions, the producer must fully document (e.g., receipts, ingredients, and tear tags) the supplementation that occurs including the amount, the frequency, and the supplements provided."

Similarly, AGA defined their standards in four main areas of production, as follows.

Diet – "Animals are fed only grass and forage from weaning until harvest."

Confinement- "Animals are raised on pasture without confinement to feedlots."

Antibiotics and hormones- "Animals are never treated with antibiotics or growth hormones."

Origin- "All animals are born and raised on American family farms."

Thus, the AGA standard is more restrictive than the USDA standard in the sense that production must be free of antibiotics and hormones. For purposes of this study, the definition of GFB is based on the USDA standard.

### 1.2. Current Scenario and Challenges Facing Grass-fed Beef Production in the U.S.

Although GFB is experiencing increasing interest (Cox et al. 2006, Umberger et al. 2002), its production is experiencing multiple challenges, including technological and marketing issues, among others (Gwin, 2009; Martin and Rogers, 2006). As per Gwin (2009), the head count of GFB animals was estimated at between 50,000 and 100,000 in 2008. As such, they were estimated to account for less than 0.5% of the total beef produced in the U.S. Pelletier, Pirog, and Rasmuseen (2010) estimated the share of GFB production to be lower than 1% of the total beef produced in the U.S. Lack of knowledge of appropriate production practices has been cited as one of the reasons for the relative low production of GFB (Gwin, 2009).

With increased interest in GFB production in recent years, potential GFB farmers are asking questions about the most profitable production methods. According to the 2007 Census of Agriculture, most of the cattle operations in the U.S. are comparatively small and operate on a fixed land area. Labor required for such farms is fulfilled mostly by land owners and their family members. Limited studies have evaluated the roles of labor and profitability in cow-calf production (Gillespie et al., 2008; Wyatt et al., 2013). Since GFB production activities can be rather labor-intensive, producers are interested to know labor use requirements and profitability across different pasture systems. In addition, there is increased interest in the environmental sustainability of agricultural production systems; few if any studies have considered the GHG emissions of GFB systems. Such issues all of particular interest to GFB production since producers and consumers of GFB are likely to value products that have original from more sustainable systems. Moreover, producers are interested in economic efficiency implications of GFB production in particular the characteristics of the most technically efficient farms.

### 1.3. Dissertation Overview and Objectives

It is clear that there is a growing interest for GFB in the U.S. Several challenges related to technological and other management issues have been identified for GFB production. This study analyzes several different technological and managerial problems and suggests appropriate measures to resolve these issues.  This dissertation is divided into five chapters. The first chapter provides an overview of the GFB industry in the U.S. The second chapter identifies the most profitable and sustainable pasture systems experimentally evaluated since a wide range of pasture systems are used to produce GFB with subtle differences among them. Since labor is an important input in GFB production, the third chapter analyzes the labor use and profitability among the pasture systems. The fourth chapter analyses the distribution of technical efficiency and the parameters that affect technical efficiency among GFB producers. The fifth chapter provides the summary and conclusions of this study.

The specific objectives of the three essays in the dissertation are:

Essay 1: Analysis of three pasture systems for profitability and economic sustainability based on three years of experimental data.

Objectives:

- To determine the most profitable pasture system
- To determine the pasture system that emits the least carbon dioxide equivalent
- To determine the trade-off between economic profit and GHG emissions.

Essay 2: Analysis of three pasture systems for labor use and profitability based on five years of experimental data.

Objectives:

- To determine the most profitable pasture system including labor.
- To determine the most profitable pasture system without labor.
- To determine the sensitivity of the results for switching among pasture systems.

Essay 3: Evaluation of the technical and economic efficiency of GFB production based on survey data.

Objectives:

- To determine the cost of production of U.S. grass-fed beef farms.
- To determine the distribution of technical efficiency of GFB production farms in the U.S.
- To determine the returns to scale of U.S. grass-fed beef farms.
- To determine the effects of farm characteristics and farmer demographics on the technical efficiency of U.S. GFB farms.

## 1.4. Data

### 1.4.1. Experimental Data

For the first and second essays, data are based on LSU AgCenter research. The research was conducted at the Iberia Research Station, Jeanerette, LA from 2009 to 2014. The following three pastures systems were planted and replicated three times in the field.

System 1: Bermudagrass in the summer and annual ryegrass in the winter.

System 2: Bermudagrass in the summer and annual ryegrass, rye, dallisgrass and clover mix (white, red and berseem) in the winter.

System 3: Bermudagrass, soybean, and sorghum sudan hybrid in the summer and annual ryegrass, rye, dallisgrass and clover mix (white, red and berseem) in the winter.

For the detail of the pasture systems, the reader is referred to Scaglia et al. (2014).

Each year, fifty-four fall-born calves were weaned in May and grouped into nine groups (each group of 6 steers) and then randomly allocated into three pasture systems with three replications. As per availability of grass, animals were moved to different sub-paddocks within the system along with portable shades and watering devices. During transition period (October to December), when green grass was not available, animals were fed bermudagrass hay produced from the same pastures. Detailed field operations including inputs, equipment and machinery used, and output produced were recorded. Based on these records, budgets were developed for each treatment replication, year group. Thus, we have 27 observations over three years and 45 observations over five years. The following Figure 1.2 illustrates how the animals were kept in the pasture systems.

To analyze the sustainability of pasture systems, GHG emissions were also recorded for the initial three years and Global Warming Potential (GWP) was estimated for each system with the modification of Liebig et al. (2010) equations for GWP.

Figure 1.2: A Photo of a Group of Six Steers in Winter, 2011, in the System 3 Pasture System Used in This Study

Photo by: Guillermo Scaglia

1.4.2. Survey Data

The third essay is based on cost and returns survey data. Information from various online sources such as www.eatwild.com, MarketMaker, and Google searches were used to find GFB producer addresses for mail survey. Addresses were collected for 1,050 farmers in all 50 states of the U.S. Figure 1.3 shows the distributions of the 1,050 GFB farmer addresses we identified for the survey.

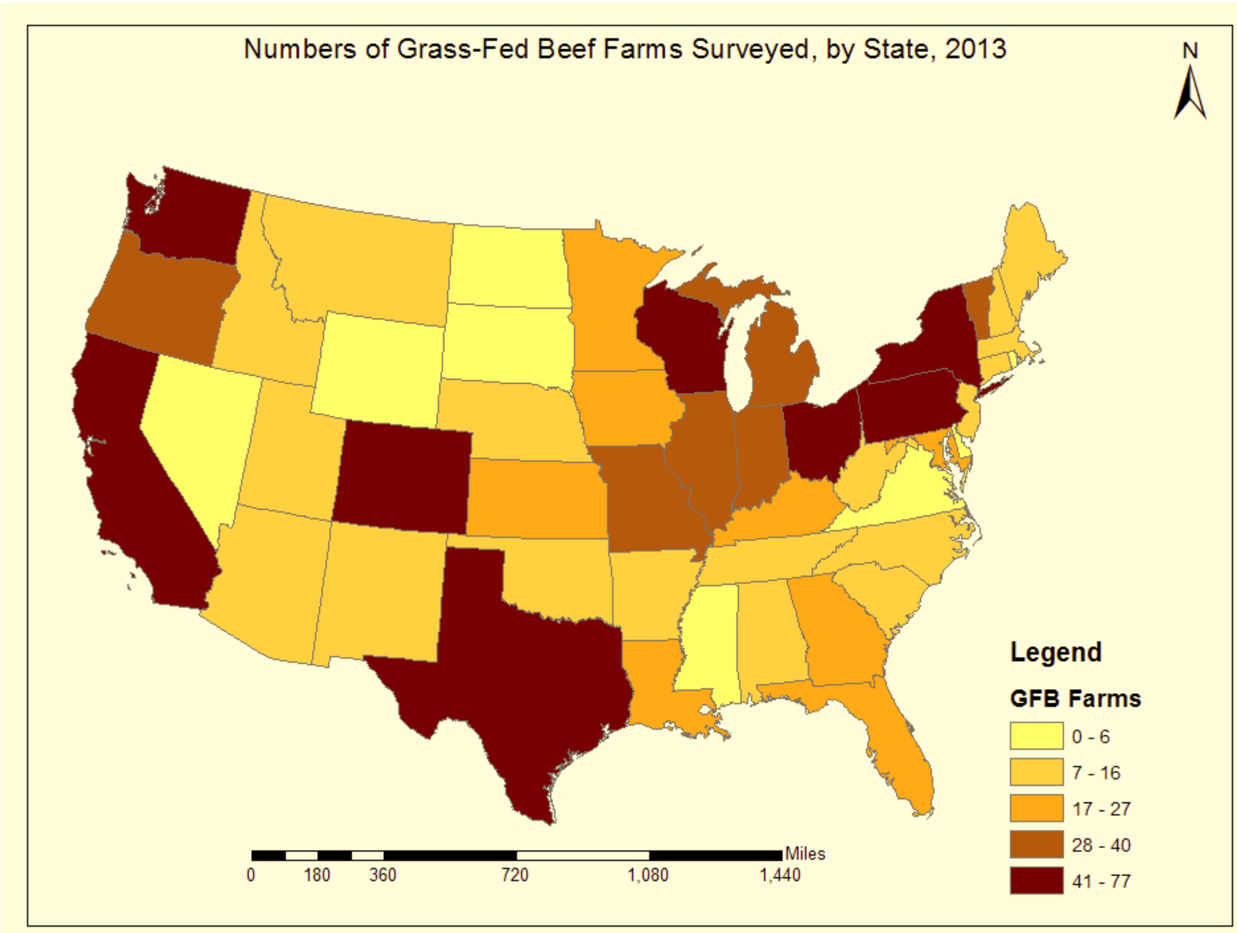

Figure 1.3. Number of U.S. Grass-Fed Beef Farms Surveyed, by State, 2013

Two surveys were conducted. The first survey collected data on farm characteristics, farmer demographics, marketing, pasture systems, production practices, goal structure, and producer preferences. This survey was sent out in July, 2013, following the Tailored Design Method of Dillman et al. (2009) with four contacts. A personally-addressed letter mentioning the rationale of the study along with a 10-page questionnaire was sent in the second week of July. A postcard reminder was sent two weeks after the first mailing. Two weeks later, a second personally-addressed letter along with a second questionnaire was sent to the farmers who had not yet responded to the survey. A postcard reminder was sent two weeks after. Three-hundred eighty-four surveys were returned from this first survey for an adjusted return rate of 41%. The distribution of survey returns shows the representation of grass-fed beef farmers in the U.S. (Figure 1.4). Please see Appendix A and B for the first survey questionnaire and its institutional approval, respectively. There was a question asking about their willingness to participate in a

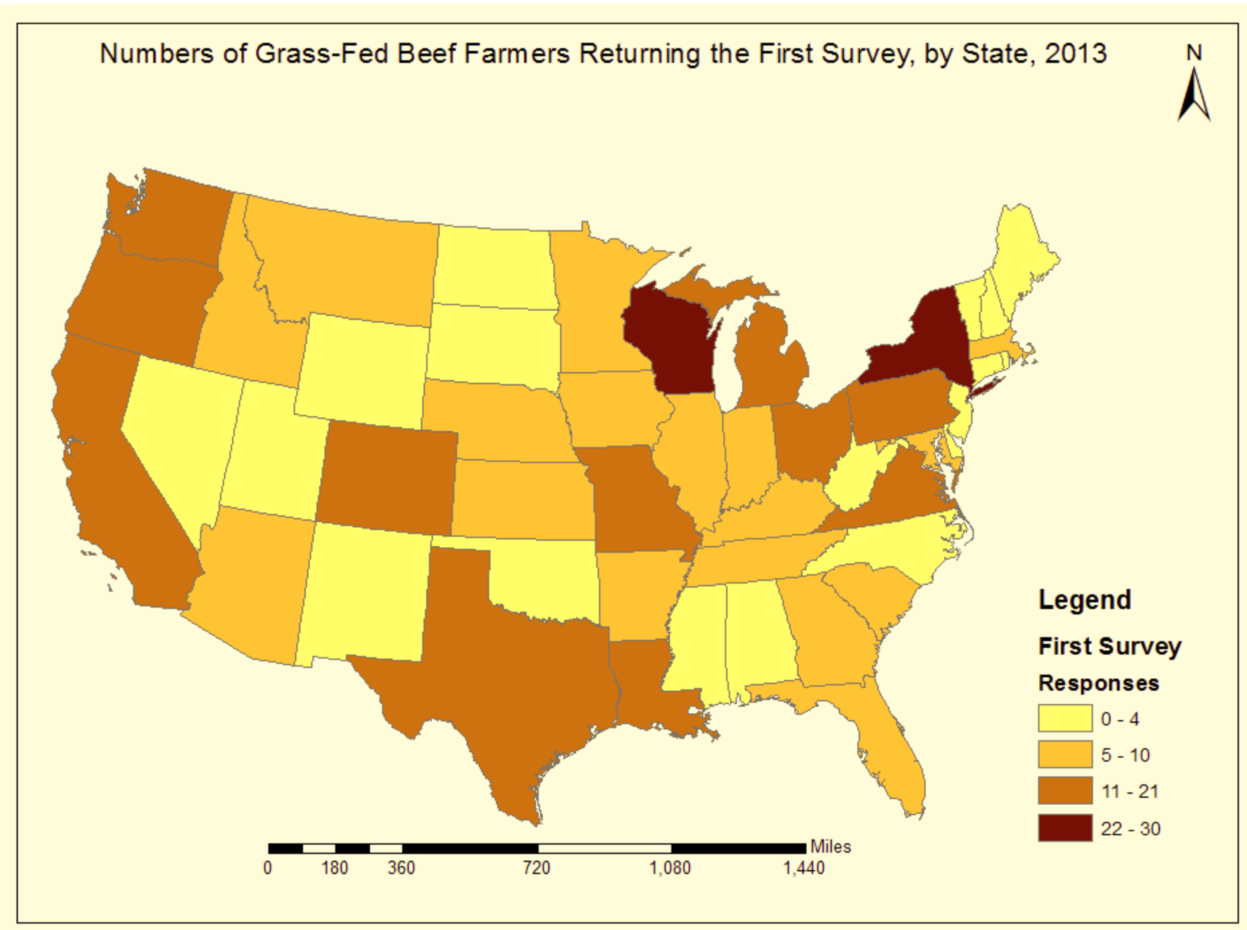


Figure 1.4. Numbers of Grass-Fed Beef Farmers Returning the First Survey, by State, 2013

follow-up cost and returns survey. We received 250 responses indicating a willingness to participate in the follow-up survey.

A cost and returns follow-up survey was sent out to the 250 GFB producers who had indicated their willingness to participate. The cost and returns survey was three pages long having various questions related to their variable and fixed inputs as well as various outputs of their farms. We received 82 usable survey responses which constitute an adjusted response rate of 33%. These responses were distributed as shown in Figure 1.5. Please see Appendix C and D for the second survey questionnaire and its institutional approval, repectively.

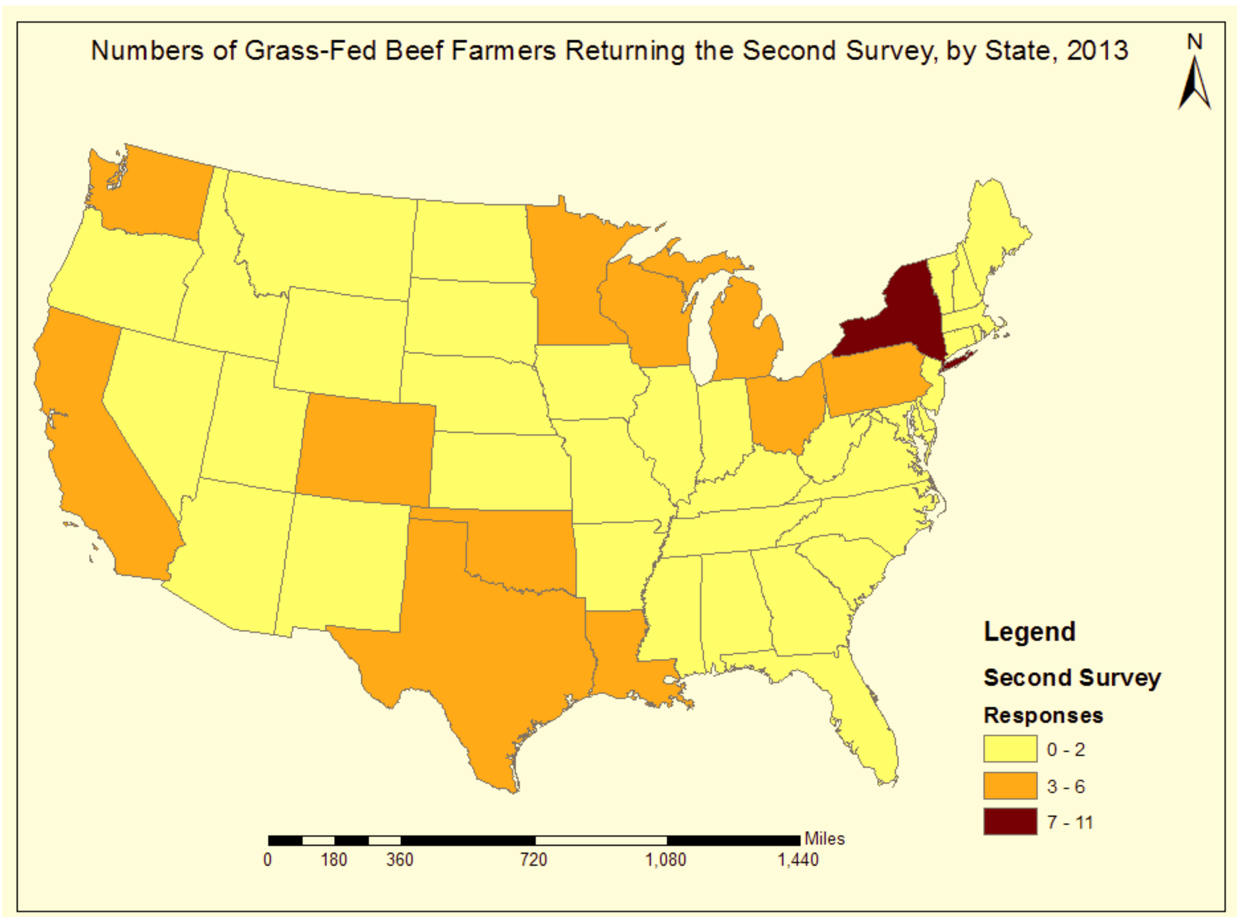


Figure 1.5. Numbers of Grass-Fed Beef Farmers Returning the Second Survey, by State, 2013

The two data sources-experimental data and farm survey data- allow for a thorough analysis of the economic implications of alternative GFB production systems.

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# CHAPTER 2: ANALYSIS OF PASTURE SYSTEMS TO MAXIMIZE THE PROFITABILITY AND SUSTAINABILITY OF GRASS-FED BEEF PRODUCTION[1]

## 2.1. Introduction

A wide range of forage management systems can be used to produce grass-fed beef (GFB), with each system resulting in potentially different productivity, profitability and sustainability outcomes. The USDA defines grass-fed beef as beef from cattle whose lifetime diet consists of only grass and other forage, with the exception of milk consumed prior to weaning; no grains are fed (USDA-AMS, 2007). Although GFB preceded grain-fed beef production as a practice of raising cattle, grain supplementation has been standard practice in cattle production since the 1950s (Schupp et al., 1979). Today, the share of GFB production is lower than 1% of the total beef produced in the U.S. (Pelletier, Pirog, and Rasmuseen, 2010). Lack of knowledge of appropriate production practices has been cited as one of the reasons for the relative low production of GFB (Gwin, 2009). With increased interest in GFB production in recent years, potential GFB farmers are asking questions about the most profitable production methods.

Over the past 50 years, studies have reported favorable carcass characteristics for grain-fed beef such as juiciness, tenderness, and marbling (Oltjen, Rumsey, and Puttnam, 1971; Young and Kaufman, 1978; Aberle et al., 1981; Fishell et al., 1985). Recently, however, with consumer concerns about human health, the environment, and animal welfare, GBF is experiencing increased demand (Wright, 2005; Mills, 2003; McCluskey et al., 2005). Umberger et al. (2002)

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[1] Published as: Bhandari B.D., J. Gillespie, G. Scaglia, J. Wang, and M. Salassi. “Analysis of Pasture Systems to Maximize the Profitability and Sustainability of Grass-Fed Beef Production.” Journal of Agricultural and Applied Economics 47,2(2015):193-212. See Appendix E.

found that 23% of U.S. consumers were willing to pay a $3.00/kg premium for GFB while Cox et al. (2006) reported 33% preferred GFB and were willing to pay premiums of $2.38-$5.63/kg. Prevatt et al. (2006) also reported a segment of U.S. consumers that preferred GFB.

Forage nutritive value can impact beef productivity and quality and, thus, it plays a crucial role in animal development and beef production (Gerrish, 2006). Various studies have compared different grazing systems for beef production, many focusing on stocking density (Lewis et al., 1990; Bertelson et al., 1993; Anderson, 1988) and some also analyzing the economics of those systems (Gillespie et al., 2008; Comerford et al. 2005). Few, however, have focused on GFB production. Surveys of GFB producers have been conducted by Lozier et al. (2005) and Steinberg and Comerford (2009). According to the latter study, the major expenses associated with GFB production were steers, land, feed, equipment, and wintering (hay or silage), the latter four of which are related primarily to forage production. Knowledge of the most profitable forage production systems would greatly benefit GEB producers.

In addition to the selection of an appropriate forage production technology for productivity and profitability, there is a need to investigate the comparative ecological sustainability of forage production systems. Greenhouse gas emissions from agricultural land play a role in total global warming potential. Pasture, as the largest land resource in the U.S., plays an important role in carbon cycling and sequestration (Follett and Reed, 2010). Since the Kyoto Protocol of 1997, studies have evaluated the feasibility of carbon sequestration from agricultural and forest land (Antle and McCarl, 2002; Liebig et al., 2010). A wide range of the compensation cost for producers for shifting their land use to the conversation reserve program ($12 to $500 per metric ton) was found in Eastern Montana depending upon the type of land, crop, and cropping intensity (Antle et al., 2001). Zeuli and Skees (2000) analyzed the challenges and opportunities for Southern U.S. agriculture to play a role in the carbon market and discussed a wide range of carbon value estimates which were similar in range to those found by Antle and McCarl (2002). Liebig et al. (2010) evaluated the GHG impacts of different grazing strategies in terms of their contributions to GWP. Limited efforts, however, have been made to evaluate agricultural management strategies in terms of profitability and GHG emissions (Nalley, Popp and Fortin, 2011; Nalley, Popp and Niederman, 2013; Williams et al., 2004). For example, McFadden, Nalley and Popp (2011), and Lyman and Nalley (2013), evaluated rice varieties in Arkansas to maximize profit and minimize GHG emissions. Despite these various efforts, development of a carbon market remains largely in the discussion stage. The present study has implications for what the development of a carbon market might do in encouraging more sustainable agricultural systems.

In this context, we evaluated the profitability and ecological sustainability of three GFB production pasture systems with different levels of management intensity and use of resources. The specific objectives of this study are, for GFB pasture systems, to: (1) determine the most profitable system; (2) determine the system with the lowest GHG emissions, and (3) determine the potential trade-off between economic profitability and GHG emission reduction. This study is unique not only because it compares the profitability of specific pasture combinations for GFB production, but also because it evaluates carbon emissions related to each of three systems throughout the study period. Trade-offs between profitability and GHG emissions are estimated for the pasture systems. Thus, this study integrates three distinct disciplines of agricultural science: agricultural economics (expenses and returns and trade-offs between greenhouse gas impact and economic profitability), animal science (pasture management and rearing of beef cattle), and soil science (analysis of carbon emissions on pasture land).

## 2.2. Analytical Techniques

This study was based on the following experimental design. Three treatments used in a field experiment at the LSU AgCenter Iberia Research Station (IRS) in Jeanerette, LA, from 2009-2010 to 2011-2012 represented forage systems with different degrees of management complexity. The three forage systems follow:

1. Forage System 1

   Bermudagrass as summer pasture; annual ryegrass as winter pasture.

2. Forage System 2

   Bermudagrass as summer pasture; dallisgrass and clover mix as fall and winter pastures; and annual ryegrass, rye, and clover mix (berseem, red, and white clovers) as winter pastures.

3. Forage System 3

   Bermudagrass, sorghum-sudan hybrid, forage soybean as summer pastures; dallisgrass and clover mix as fall and winter pastures; and annual ryegrass, rye, and clover mix (berseem, red, and white clovers) as winter pastures.

These systems were chosen as representative of the types of systems currently being used for GFB production in the U.S. Gulf Coast Region. The least complex and relatively common system in the Gulf Coast Region is represented by System 1, which consists of a perennial summer and winter annual pasture. System 2 consists of clover mixtures and dallisgrass as an addition to the winter pasture in System 1. This would help to extend the grazing period in the

Fall and reduce the requirement of hay feeding. In System 3, sorghum sudan hybrid and soybean are added as summer pastures in addition that in to System 2, which would help to satisfy the nutritional requirements of the steers. Thus, System 1 is the least and System 3 is the most complex system.

The same pastures were used for each treatment each year. Every year, the experiment began in May and ended by the end of April of the following year. The three forage systems were managed in different sub-paddocks at the IRS, rotated among the sub-paddocks based on forage availability. Annually, 54 7 to 8 month old Fall-born steers were assigned to one of the three forage systems immediately after weaning and remained until time of harvest at age 17-19 months. The steers were blocked at weaning by body weight into 9 groups (6 steers/group). Each group was randomly assigned to one of the three treatments, each of which was replicated three times. During the transition period when forage availability was low (mid-November to December), animals were fed hay produced in the paddocks allocated to the system/ replication group. Records were kept on the amount of hay fed to each group. Constructed portable shades were made available for the animals in each group. They were moved along with the animals when rotated. Water and mineral mix were available at all times. The stocking rate was 1 hectare per animal for each entire system. Although this may seem to be a relatively low stocking rate at first glance, unpublished survey results of a mail survey we sent to all identified Southern U.S. GFB producers show that it is not uncommon to have a stocking rate in this range considering, as the believe, the lowest forage production period in the year.

Detailed cost and input records were kept for each pasture by year, with sheets on which the records were to be kept developed by the authors. These records detailed the agronomic operations, labor activity, and input usage in each pasture, recorded in a field book. These records were used to develop detailed cost and return estimates for each treatment/replication. Budgets included returns, direct expenses, fixed expenses, and land rent. The expenses of seed, fertilizer, pesticide, minerals, medication, twine, fuel, purchased weaned steers, repair and maintenance of machinery, and interest on operating capital were included in the direct expenses. Depreciation and interest on machinery (trucks, tractors, and other implements), permanent fencing, and temporary fencing were included in the fixed expenses. The opportunity cost of land rental was included.

Table 2.1 includes annual prices of inputs and outputs. Most of the input prices are those used by Boucher and Gillespie (2009, 2010, and 2011) for cost and return estimates for cattle and forage production. Weaned calf prices from Louisiana Agricultural Statistics 2011 (LSU Agricultural Center, USDA-NASS, 2012) were used. We used calf prices from the second quarter of each year from 2009 to 2011 since animals entered the experiment in May. Hay was measured as large bale of an average weight of 430kg. Hay prices were determined based on those listed on the Weekly Texas Hay Report (USDA-TX, 2010, 2011, and 2012) for fair quality hay, assuming any left-over hay was sold in April after harvest of the animals. The grass-fed steer price was based on USDA-Economic Research Service (2012) published prices for fed steers in the second quarter of each year and adjusted by adding $0.44/kg to the fed steer price, as suggested by a manager of one of the larger grass-fed beef production firms. As the records were kept by group for each year, there were nine sets of records per year, for a total of 27 sets of records and 27 resulting cost and returns estimates for the three years.

Table 2.1. Prices of Inputs and Outputs for the Experimental Years

| Inputs/outputs | Unit | Price in US$ | | |
|---|---|---|---|---|
| | | 2009 | 2010 | 2011 |
| Urea | Kilogram | 0.40 | 0.35 | 0.42 |
| Gramoxone Max | Liter | 10.57 | 11.54 | 11.54 |
| Grazon P+D | Liter | 8.47 | 10.44 | 8.18 |
| Roundup Original Max | Liter | 13.86 | 15.32 | 12.85 |
| Outrider | Liter | 676.28 | N/A | N/A |
| Platoon | Liter | N/A | N/A | 3.70 |
| Malathion | Liter | N/A | 8.98 | 8.94 |
| Sevin 80% WP | Kilogram | 13.51 | 15.01 | 16.20 |
| Bovishield | Dose | 2.50 | 2.50 | 2.50 |
| One Shut | Dose | 2.50 | 2.50 | 2.50 |
| Sweetilix | Block | 18.00 | 18.00 | 18.00 |
| Ultrabac 8 | Dose | 0.40 | 0.40 | 0.40 |
| Vigortone 3V2 | Bag | 26.20 | 26.20 | 26.20 |
| Vigortone 3V5 | Bag | 17.13 | 17.13 | 17.13 |
| Weanling Calf | Kilogram | 2.17 | 2.51 | 2.51 |
| Twine | Ton | 0.75 | 0.75 | 0.75 |
| Berseem Clover Seed | Kilogram | 4.72 | 4.74 | 7.72 |
| Red Clover Seed | Kilogram | 5.51 | 6.61 | 2.65 |
| White clover Seed | Kilogram | 5.51 | 7.05 | 6.83 |
| Rye Seed | Kilogram | 0.49 | 0.97 | 0.99 |
| Ryegrass Seed | Kilogram | 1.34 | 1.54 | 1.10 |
| Soybean Seed | Kilogram | 1.23 | 1.17 | 1.32 |
| Sorghum Sudan Seed | Kilogram | 1.04 | 1.76 | 1.76 |
| Hay[a] | Bale | 45.00 | 40.00 | 82.50 |
| Steers at Harvest[*] | Kilogram | 2.56 | 2.93 | 3.11 |
| Diesel Fuel | Liter | 0.58 | 0.61 | 0.73 |

[a] Although the prices of hay and steer at harvest were tabulated as 2009, 2010, and 2011, those were based on USDA prices in the following years (2010, 2011, and 2012) since the harvesting and selling of hay and steers was in the second calendar year of the experiment.

Note: N/A indicates data not available.

Table 2.2 shows fixed inputs with their annual fixed and repair and maintenance costs. These costs were calculated according to their useful life as the costs of capital and depreciation. Similarly, the fixed expenses of machinery and equipment were estimated as depreciation and opportunity cost of capital (interest) by hours of use, assuming a useful life of a fixed number of hours as shown in Boucher and Gillespie (2011).

Table 2.2. Prices of Fixed Inputs, Machinery and Equipment

| Fixed Input Annual Costs in US$ | | | |
|---|---|---|---|
| Input Structure | Units | Repair and Maintenance | Fixed costs |
| Fence Electric | km | 23.61 | 156.19 |
| Fence 5 wire | km | 130.49 | 302.30 |
| Hay Rack | each | 9.04 | 26.27 |
| Shade Structure | each | 3.48 | 72.65 |
| Shade Cloth | each | 5.30 | 64.25 |
| Water Tank and Pump | each | 40.00 | 132.50 |
| Machinery and Equipment Costs in US$ | | | |
| Machinery/Equipment | | Direct Costs/ hour | Fixed Costs/hour |
| Mower Conditioner | | 10.79 | 12.89 |
| Hay Rake | | 2.43 | 3.16 |
| Hay Tedder | | 2.45 | 3.67 |
| Hay Fork | | 0.09 | 0.22 |
| Baler Round | | 13.98 | 18.56 |
| Mower Drum | | 4.68 | 5.59 |
| Boom Sprayer | | 2.35 | 3.12 |
| Tractor (40-59hp) | | 6.48 | 4.42 |
| Tractor (60-89hp) | | 10.05 | 7.81 |
| Tractor (90-115hp) | | 14.31 | 12.52 |

Differences in fixed expenses, variable expenses, gross returns, and net returns among treatments were determined using a mixed model with fixed treatments, and years as fixed repeated measures effects. The Kenward-Roger Degrees of Freedom method was used (Kenward and Roger 1997).

Since the cost and returns analysis is based on 27 observations, we used simulation and dominance techniques to strengthen the results of this research. Based on historical data (10 years 2002-2011) on prices of inputs (fertilizer, fuel, and calf) and outputs (hay and steer), 1,000 randomly simulated values were developed using Simetar, a commercial mathematical simulation software package (Richardson et al., 2008). Similarly, hay yield was estimated based on 10 years of historical rainfall data at the IRS and 1,000 randomly simulated values were developed. Other input prices and quantities and steer yield were taken as constant since we did not observe significant variation in these inputs and output prices and quantities over the course of the experiment. Based on these simulated values and constant values, 1,000 net returns for each of the systems were developed.

Using the 1,000 simulated net returns, we estimated certainty equivalents (CE) assuming different risk aversion coefficients for each system according to the relationship outlined by Hardakar et al. (2004). The CE is the net return value held with certainty at which decision maker is indifferent to a risky distribution of net return values. Estimation of the CE depends on the utility function of the decision maker. Equation (1) gives the relationship between the utility function $U(w)$ and the absolute risk aversion coefficient, $r_a(w)$

(1) $U(w) = -exp(-r_a(w)),$

where w is the wealth or income associated with the choice. The absolute risk aversion coefficient is defined as the negative ratio of the second and first derivatives of the utility function as shown in equation (2).

(2) $r_a(w) = -\frac{u''(w)}{u'(w)}$

The relationship between the absolute risk aversion coefficient and the relative risk aversion coefficient, $r_r(w)$ is expressed as:

(3) $r_a(w) = r_r(w)/w.$

The CE for a random sample of size *n* from risky alternatives *w* is estimated as follows, as shown by Hardaker et al. (2004).

(4) $CE\big(w, r_a(w)\big) = ln\left\{\left(\frac{1}{n}\sum_i^n exp(-r_a(w)w_i)\right)^{-1/r_a(w)}\right\}$

As Anderson and Dillon (1992) have proposed, a general classification of relative risk aversion coefficients falls in the range of 0 for risk neutral to 4 for highly risk averse. Absolute risk aversion coefficients were obtained by dividing a range of relative risk aversion coefficients (0 to 4) by the estimated mean net return of System 3. This gives the maximum absolute risk aversion coefficient of 0.0024, which is used in a stochastic efficiency with respect to function (SERF) analysis. SERF is a means to evaluate the risky alternatives in terms of certainty equivalents for a specified range of absolute risk aversion coefficients. It is superior to stochastic dominance with respect to function since latter only makes the pairwise comparison (Hardakar et al., 2004). The result is graphed to analyze the dominance by system. We used a similar method to that of Hardakar et al. (2004) to analyze the SERF among the systems.

2.2.1. Estimating Carbon Emissions

Soil carbon emission data and soil samples were collected and analyzed within the three pasture systems. There were seven different forage categories. For each category, gas sampling for carbon dioxide ($CO_2$) and atmospheric methane ($CH_4$) flux was carried out. Four chambers (replicates) were placed in pastures for each forage category. Samples were taken monthly throughout the experiment. Chamber gas samples at each location were taken at regular intervals of 0, 30, and 60 minutes. These samples were analyzed by gas chromatography equipped with a methanizer and flame ionization detector. The $CO_2$ and $CH_4$ fluxes were computed from the rate of change in chamber concentration, chamber volume, and soil surface area. We were, thus, able to compute the annual average $CO_2$ equivalent carbon emissions by pasture system. Since $CO_2$ equivalent carbon emissions from the atmospheric $CO_2$ flux, $CH_4$ flux and $N_2O$ flux data were collected based on different pasture types, not from the individual sub-paddocks, we could not develop 27 separate sets of data for $CO_2$ emissions specific to a system. Therefore, we could not apply statistical analysis on $CO_2$ emissions, so only the arithmetic means for each system were compared for the analysis.

The net global warming potential (GWP) in kg of $CO_2$ equivalent in each system was determined by adding the emitted $CO_2$ equivalents from seven factors as shown in the following equation used by Liebig et al. (2010), with modification:

(5) $GWP = NP + EF + CO_2\ Flux + N_2O\ Flux + CH_4\ Flux + DU + PP,$

where GWP is measured in kg of $CO_2$ equivalent emissions summing from different sources; NP is the $CO_2$ equivalent emission by nitrogen fertilizer production; EF is the $CO_2$ equivalent emission via thorough enteric fermentation; $CO_2$ flux is the $CO_2$ equivalent emission through atmospheric $CO_2$ surrounding the pasture; $N_2O$ flux is the $CO_2$ equivalent emission through atmospheric nitrous oxide ($N_2O$) flux; $CH_4$ flux is the $CO_2$ equivalent emission through $CH_4$ flux; DU is the $CO_2$ equivalent emission by diesel use (which includes diesel used in fertilizer and pesticide application, tillage, and hay operations); and PP is the $CO_2$ equivalent emission by pesticide production.

Equation (5) was modified from Liebig et al. (2010) by replacing the change in soil organic carbon with $CO_2$ flux, as the change in soil carbon as measured in the study through soil sampling was barely noticeable over the three year period of our study. A much longer period of soil sampling would have been required to begin to detect differences in soil carbon, presenting challenges for the collection of such data in most studies of this type. Additionally, in Liebig et al. (2010), NP consists of two parts, i.e. nitrogen production and application. In our study, the application portion is included in DU. Since Liebig et al. (2010) did not apply any pesticides or include any field operations, DU and PP were not included in their equations.

Nitrogen fertilizer used in each system was aggregated based on annual use in the respective pasture systems; $CO_2$ equivalent emission from NP was computed as in Liebig et al. (2010). Similarly, $CO_2$ equivalent emission from EF was computed as in Liebig et al. (2010) where they assumed similar $CO_2$ equivalent emissions from EF per animal among different systems. Atmospheric $CO_2$ flux, $N_2O$ flux, and $CH_4$ flux were calculated based on laboratory analysis of field samples. The conversion of $CO_2$ flux to $CO_2$ equivalent emission was conducted by multiplying by the conversion factor 3.667 while the conversions of $N_2O$ flux and $CH_4$ flux were conducted by multiplying by conversion factors of 298 and 25, respectively, as in Liebig et al. (2010). The carbon equivalent (CE) emission from DU was estimated by multiplying the conversion factor of 0.94 kg CE per kg of diesel as in Lal (2004), which was further converted to $CO_2$ equivalent emission by multiplying by the conversion factor, 3.667. Pesticide used in each system was aggregated based on annual use. Then the carbon equivalent emission from PP was calculated by summing CE from different pesticides used as in Lal (2004)[2] and further converted into $CO_2$ equivalent emission by multiplying by the conversion factor 3.667. As the conversion factors in Lal (2004) are based on kilograms of active ingredients, liquid formulations were converted to quantities by using the specific gravity of the pesticides in solution as a multiplying factor (Appendix F). Since we could not find the specific conversion factors for Picloram, Sulfosulfuran and Dimethylamine salt of 2,4-D to estimate $CO_2$ equivalent emission, the general conversion factor for herbicides, 4.4, was used as estimated in West and Marland (2002). Since these three active ingredients of herbicides contributed less than 1% of the total pesticides used for this experiment, they would have minimal impact on the $CO_2$ equivalent emission.

Equation (5) is further modified by subtracting the $CO_2$ equivalent carbon sequestration from hay surplus (HS):

(6) $GWP = NP + EF + CO_2\ Flux + N_2O\ Flux + CH_4\ Flux + DU + PP - HS.$

Hay surplus is the quantity of hay biomass remaining after consumption by the animals in the respective pasture systems. Carbon sequestered in this HS is calculated by subtracting the 12% moisture from hay biomass and multiplying by the conversion factor 0.475. This is then converted into $CO_2$ equivalent by multiplying by the conversion factor 3.667. Since HS fixed atmospheric carbon, it would negatively affect the net GWP. Therefore, it has a negative sign in (6). Ultimately, this carbon sequestered in the hay surplus would likely be released to the

[2] CE conversion factors for different active ingredients as per Lal (2004) are: 1.7 for 2,4-D, 9.1 for Glyphosate, 9.2 for Paraquat, 4.6 for Malathion, and 9.1 for Carbaryl.

atmosphere since the hay surplus will be used for consumption by animals. Therefore, we calculated the GWP with and without including hay surplus.

The value of carbon that would entice farmers to switch management practices (treatments) was determined. The value of carbon emissions was determined by comparing the total amount of $CO_2$ equivalent GWP and economic profit per animal per year among the systems, as in equation (7).

(7) $\pi_k = \pi_l + C$,

where $\pi_k$ is the profit associated with system *k* (without placing economic value for $CO_2$ equivalent carbon emissions), $\pi_l$ is the profit associated system *l* (without placing economic value for $CO_2$ equivalent emissions), and *C* is the value of reduced $CO_2$ equivalent carbon emissions that would induce a change from system *k* to system *l*.

## 2.3. Results and Discussion

### 2.3.1. Economic Profitability by System

Return, expense, and profit estimates for the three systems are presented in Table 2.3. Results are reported on a per-steer basis. Since the stocking density is 1 steer per hectare, this can be taken as a per hectare basis as well. Differences in steer income were not found among the treatments in this experiment because the animal weights at the time of harvest did not differ significantly among the systems. Mean weights of finished animals were 462 kg, 458 kg, and 459 kg for Systems 1, 2, and 3, respectively (Table 2.4). Hay income differed significantly among the systems, greatest in System 1 and least in System 3 because hay production was more extensive in bermudagrass and ryegrass pastures than in other pastures. System 1 had greater

Table 2.3. Revenue, Expenses, and Profit per Treatment (US$ per Animal)

| Revenue / Expenses | System 1 | System 2 | System 3 |
|---|---|---|---|
| INCOME | | | |
| Steer Income | 1,324.41 | 1,330.17 | 1,311.61 |
| Hay Income | 804.20[bc] | 653.37[ca] | 460.31[ab] |
| Total Income | 2,128.61[bc] | 1,983.56[ca] | 1,771.94[ab] |
| EXPENSES | | | |
| Fertilizer | 238.37[bc] | 173.50[ac] | 145.52[ab] |
| Pesticide | 48.54 | 45.65 | 52.82 |
| Livestock | 620.98 | 622.93 | 623.35 |
| Twine | 3.96[bc] | 2.91[a] | 2.41[a] |
| Seed | 68.52[bc] | 142.37[ac] | 201.89[ab] |
| Minerals, Medication | 22.17[bc] | 22.69[a] | 22.65[a] |
| Diesel Expense | 74.96[bc] | 56.46[a] | 48.03[a] |
| Repair and Maintenance | 64.96[bc] | 51.76[a] | 48.06[a] |
| Interest on Operating Capital | 47.22 | 48.07 | 46.56 |
| Total Direct Expense (D) | 1,190.28 | 1,161.93 | 1,192.02 |
| Return over Total Direct Expense | 938.26[c] | 816.57[c] | 579.87[ab] |
| Fixed Expense (F) | 214.48[bc] | 170.04[ac] | 147.24[ab] |
| Total Expenditure (D+F) | 1,404.78 | 1,337.07 | 1,339.39 |
| Return over Specified Expenses | 723.44[c] | 646.44[c] | 432.50[ab] |
| Residual Return | 641.33[c] | 572.17[c] | 360.39[ab] |
| Residual Returns per Labor Hour | 33.65 | 35.35 | 25.04 |
| Residual Returns with Labor | 452.35[c] | 411.30[c] | 217.43[ab] |

Notes: Residual Return = Total Income - Direct Expense - Fixed Expense - Land Rent. System 1 represents the simplest pasture system including bermudagrass and ryegrass. System 2 includes a clover mix in addition to grasses in System 1, and System 3 includes sorghum sudan hybrid and soybean in addition to the forage in System 2.

[a] Means differ significantly from System 1 within rows at P <0.05.

[b] Means differ significantly from System 1 within rows at P <0.05.

[c] Means differ significantly from System 1 within rows at P <0.05.

Table 2.4. Steer and Hay Measures

| | Average Weight per Steer in Kilogram | | Number of Hay Bales | |
|---|---|---|---|---|
| System | Initial | Final | Produced | Fed |
| System 1 Average | 259 | 462 | 96 | 6 |
| 2009 | 255 | 461 | 54 | 7 |
| 2010 | 247 | 459 | 148 | 4 |
| 2011 | 273 | 466 | 86 | 6 |
| System 2 Average | 260 | 458 | 80 | 5 |
| 2009 | 258 | 445 | 81 | 7 |
| 2010 | 246 | 469 | 101 | 3 |
| 2011 | 275 | 459 | 58 | 4 |
| System 3 Average | 260 | 459 | 59 | 5 |
| 2009 | 256 | 440 | 64 | 6 |
| 2010 | 247 | 463 | 73 | 5 |
| 2011 | 275 | 474 | 40 | 5 |

Note: System 1 represents the simplest pasture system including bermudagrass and ryegrass. System 2 includes a clover mix in addition to grasses in System 1, and System 3 includes sorghum sudan hybrid and soybean in addition to the forage in System 2.

proportions of bermudagrass and ryegrass pasture than System 3. Little hay was made with clovers, sorghum sudan, soybean, etc., as there was little excess forage to be harvested in those crops. Average gross returns per steer were $2,129, $1,984 and $1,772, for Systems 1, 2 and 3, respectively, non-inclusive of any partial carbon sequestration benefits. Each differed significantly from the others. The gross return was highest in System 1 and lowest in System 3 due primarily to the differences in hay income among these systems.

Fertilizer expense for System 1 was significantly greater than for Systems 2 and 3. This was due to higher usage of N-fixing legumes in Systems 2 and 3, which substituted for commercial N fertilizer. Pesticide expense did not differ significantly among the systems although it was numerically slightly greater in System 3 due to higher use of Outrider, which was not used in System 1. Livestock expense did not differ among the systems because equal-weight weaned animals were used across the treatments. Twine expense was greater in System 1 than in Systems 2 and 3 because it was used on more bales of hay produced. Seed expense differed among the three systems, with the lowest in System 1 and the highest in System 3. This was due to the greater diversity of pastures in System 3 compared to only bermudagrass and ryegrass in System 1, the former of which is a permanent (perennial) pasture. Instead of including variable expenses for seeding bermudagrass pastures (assuming these had been previously established as permanent pastures), the establishment expense for bermudagrass was included as a fixed expense as in Boucher and Gillespie (2009, 2010, and 2011). Minerals and medication expenses were greater in Systems 2 and 3 than in System 1. This was due to the use of Sweetlix to control bloat in Systems 2 and 3 with legume pastures, but not in System 1. Diesel expense was greater in System 1 than Systems 2 and 3, primarily because of the greater use of machinery for hay cutting and baling in System 1. Similarly, repair and maintenance expense was also greater in System 1 than Systems 2 and 3 because of greater use of machinery for hay cutting and baling.

In total, direct expenses did not differ significantly among the systems, the major reason being relatively high fertilizer and diesel expenses in System 1 and higher seed expenses in System 3. The return over direct expenses was higher for Systems 1 and 2 than for System 3. Fixed expense differed among the systems. Assuming 50 animals on the farm, System 1 consisted of 4.18 kilometers of permanent fencing and 0.89 kilometers of temporary fencing. System 2 included 3.99 kilometers of permanent and 0.47 kilometers of temporary fencing. System 3 included 4.25 kilometers of permanent fencing only. Fixed cost was highest for System 1 due primarily to the greater use of machinery for hay harvesting and baling and the fixed expense associated with establishing bermudagrass pastures. Altogether, total specified expenses per steer were $1,405, $1,337 and $1,339 for Systems 1, 2 and 3, respectively.

Net returns per steer were $641, $572, and $360 for Systems 1, 2, and 3, respectively, with the net profit of Systems 1 and 2 being significantly greater than that of System 3. The net return estimates are in the range of magnitudes found by Steinberg and Comerford (2009), -$198±1596.90 per steer. The average labor hours required for Systems 1, 2, and 3 were 19.1, 16.2, and 14.4, respectively, and returns per labor hour were $34, $35, and $25 for Systems 1, 2, and 3, respectively. When we considered the labor and management expenses from the residual returns, returns per steer were $452, $411, and $217 for Systems 1, 2, and 3, respectively (Table 1.3).

Results of the SERF analysis are presented in Figure 2.1. The results show that Systems 1 and 2 clearly dominate System 3 and confirm the findings of the cost and returns analysis. Due to the stochastic nature of hay production in System 1, decision makers with risk aversion coefficients of 0.0007 or less would choose System 1 over System 2 while decision makers having risk aversion coefficients greater than 0.0007 would choose System 2 over System 1. The coefficient of absolute risk aversion is a relative term and its interpretation is also relative. Thus, the results show that more risk averse producers would choose System 2 while less risk averse producers would choose System 1. System 2 had associated net returns that were less variable than in System 1 due to higher variability of hay production in System 1.

### 2.3.2. Greenhouse Gas Emissions

Annual $CO_2$ emissions data were collected by pasture type and aggregated for each pasture system. Estimated $CO_2$ equivalent emissions from NP; EF; $CH_4$, $N_2O$ and $CO_2$

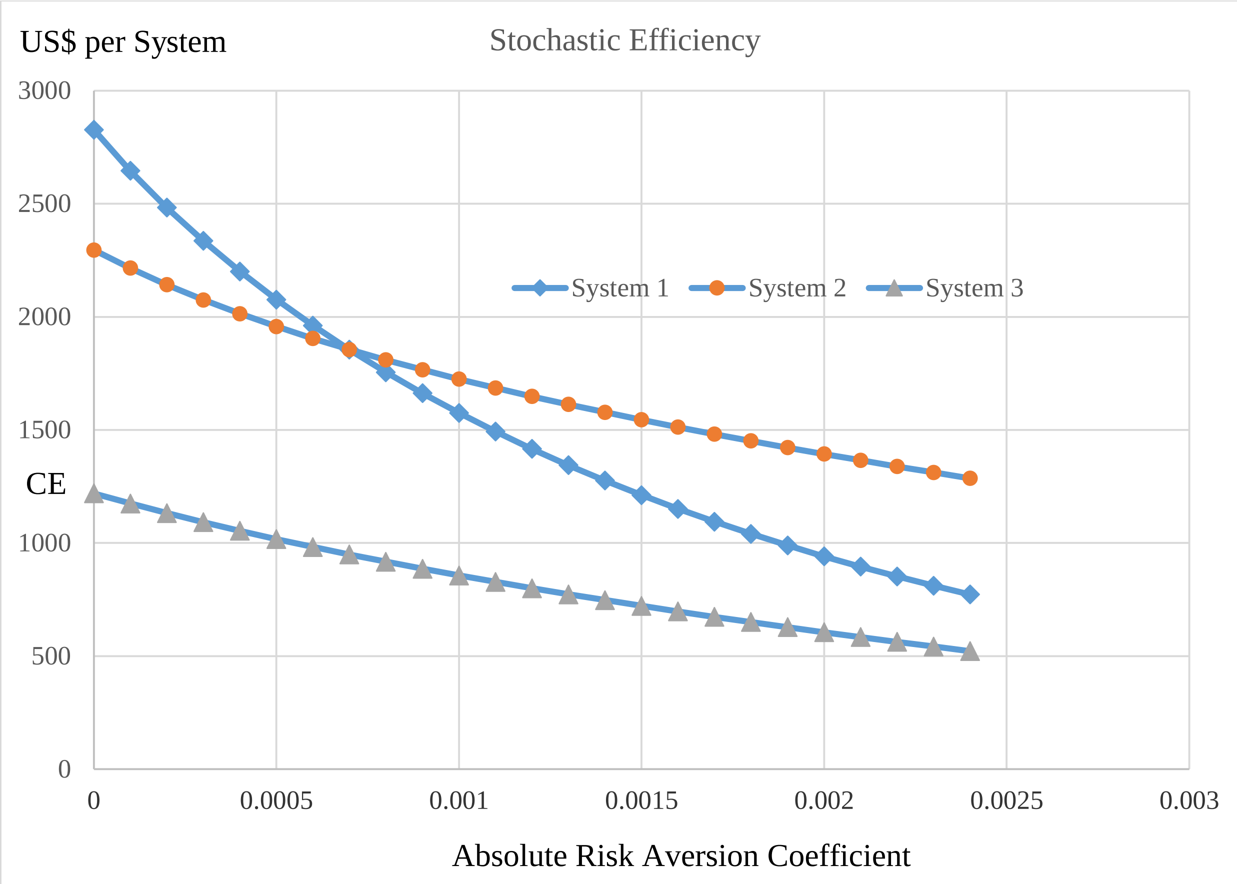


Figure 2.1. Stochastic Efficiency with Respect to a Function among the Systems

Notes: System 1 represents the simplest pasture system including bermudagrass and ryegrass. System 2 includes a clover mix in addition to grasses in System 1, and System 3 includes sorghum sudan hybrid and soybean in addition to the forage in System 2.

fluxes; DU; and PP per system as well as $CO_2$ equivalent fixation by HS per system are presented in Table 2.5, as are the net annual GWP with and without HS per system and per animal per year. Since hay surplus from each system was sold and income due to hay sale was included in economic profit measures, GWP per steer per year was also estimated without subtracting HS as in (5). Although the amount of GWP per steer per year was slightly higher in each system without HS, the difference was not great.

Table 2.5. Global Warming Potential (GWP) as Kilograms $CO_2$ Equivalent per Year among Systems with and without Hay Surplus per Treatment per Animal

| | Kilograms $CO_2$ Equivalent per Year from Different Sources | | | | | | | | GWP with HS | | GWP without HS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| System | NP | EF | $CH_4$ F | $N_2O$ F | $CO_2$ F | HS | DU | PP | GWP | GWP/animal | GWP | GWP/animal |
| System 1 | 5,319 | 29,401 | 2,276 | 120,970 | 253,994 | 3,389 | 2,121 | 644 | 411,336 | 68,556 | 414,725 | 69,120 |
| System 2 | 3,875 | 29,401 | 819 | 33,164 | 276,142 | 2,827 | 1,606 | 523 | 342,702 | 57,117 | 345,528 | 57,588 |
| System 3 | 3,525 | 29,401 | 2,007 | 36,520 | 242,364 | 2,023 | 1,383 | 507 | 313,684 | 52,281 | 315,707 | 52,618 |

Notes: System 1 represents the simplest pasture system including bermudagrass and ryegrass. System 2 includes a clover mix in addition to grasses in System 1, and System 3 includes sorghum sudan hybrid and soybean in addition to the forage in System 2. NP represents the kilograms of $CO_2$ equivalent of emissions from the nitrogen fertilizer production. EF represents the kilograms of $CO_2$ equivalent of emissions from enteric fermentation, $CH_4$ F represents the kilograms of $CO_2$ equivalent of emissions from atmospheric $CH_4$ flux. $N_2O$ F represents the kilograms of $CO_2$ equivalent of emissions from atmospheric $N_2O$ flux. $CO_2$ F represents the kilograms of $CO_2$ equivalent of emissions from atmospheric $CO_2$ flux. HS represents the kilograms of $CO_2$ equivalent of emissions from the hay surplus. DU represents the kilograms of $CO_2$ equivalent emissions from diesel used and PP represents the kilograms of $CO_2$ equivalent of emissions due to pesticide production.

NP represents the kg of $CO_2$ equivalent of emissions from the nitrogen fertilizer production. EF represents the kg of $CO_2$ equivalent of emissions from enteric fermentation, $CH_4$ F represents the kg of $CO_2$ equivalent of emissions from atmospheric $CH_4$ flux. $N_2O$ F represents the kg of $CO_2$ equivalent of emissions from atmospheric $N_2O$ flux. $CO_2$ F represents the kg of $CO_2$ equivalent of emissions from atmospheric $CO_2$ flux. HS represents the kg of $CO_2$ equivalent of emissions from the hay surplus. DU represents the kg of $CO_2$ equivalent emissions from diesel used and PP represents the kg of $CO_2$ equivalent of emissions due to pesticide production.

System 3 produced the lowest annual GWP per steer, 52,281 kg of $CO_2$ equivalent GWP, while System 1 produced the highest, 68,556 kg of $CO_2$ equivalent GWP. On average, 3,735 kg, 2,721 kg and 2,475 kg total of nitrogen fertilizer were used annually for Systems 1, 2, and 3, respectively. Due to the higher use of N fertilizer in System 1, $CO_2$ produced through NP, $CH_4$ flux and $N_2O$ flux was highest in that system, which contributed to the highest GWP relative to the other pasture systems. Diesel consumption was highest in System 1 and lowest in System 3 due to higher machinery use for hay harvesting and nitrogen fertilizer application. On average, 724 liters, 548 liters, and 472 total liters of diesel were used annually for Systems 1, 2, and 3, respectively. Therefore, $CO_2$ equivalent emission due to the use of diesel was highest in System 1 and lowest in System 3.

Four herbicides and two insecticides were used in the experiment. Annual average use of these pesticides per system is presented in the Table 2.6. The most heavily used pesticide was Roundup Original. On average, 23 liters, 18 liters and 20 liters of Roundup Original were used in Systems 1, 2, and 3, respectively. Outrider, Gramoxone, and Platoon were not used in System 1. Higher quantities of pesticides were used in System 1 than in Systems 2 or 3. $CO_2$ equivalent

Table 2.6. Annual Average Use of Pesticides by System, per Replication (~6 hectares or 6 animals)

| System | Roundup Original | Grazon P+D | Outrider | Gramo xone | Platoon | Malathion | Sevin 80 WP |
|---|---|---|---|---|---|---|---|
| | Liters | | | | | | Kilograms |
| System 1 | 22.73 | 3.12 | 0.00 | 0.00 | 0.00 | 10.76 | 1.46 |
| System 2 | 18.18 | 4.61 | 0.03 | 0.63 | 0.58 | 6.94 | 1.02 |
| System 3 | 19.56 | 3.77 | 0.03 | 0.84 | 0.26 | 3.47 | 0.21 |

Notes: System 1 represents the simplest pasture system including bermudagrass and ryegrass. System 2 includes a clover mix in addition to grasses in System 1, and System 3 includes sorghum sudan hybrid and soybean in addition to the forage in System 2.

emission from PP was greater in System 1 than in Systems 2 and 3, due to greater pesticide use in System 1. Liebig et al. (2010) studied the impact of different grazing management strategies on GWP with three different grazing systems and found that heavily grazed and moderately grazed pastures had negative net GWP. Only the crested wheatgrass pasture had positive net GWP that differed significantly from two other systems. We cannot compare our results directly to theirs since they examined differences in soil organic carbon over a 50 year period.

Comparing profitability and GHG emissions, the following trade-offs are shown and presented in Table 2.7. System 3 had $235 including labor expense ($281 excluding labor expense) lower net profit per steer and 16,275 kg lower $CO_2$ equivalent GWP per steer than System 1. Thus, if reduced $CO_2$ equivalent emissions were valued at $0.014/kg including labor expense (or $0.017/kg excluding labor expense), then Systems 1 and 3 would be economically equivalent. Similarly, System 3 had $194 including labor expense ($212 excluding labor expense) lower net profit per steer and 4,836 kg lower $CO_2$ equivalent GWP per steer than System 2. Therefore, if reduced $CO_2$ equivalent emissions were valued at $0.040/kg including labor expense ($0.044/kg excluding labor expense), then Systems 2 and 3 would be

Table 2.7. Trade-Offs between the Three Systems, per Animal

| Comparison among Systems | System 3 vs. System 1 | System 3 vs. System 2 | System 2 vs. System 1 |
|---|---|---|---|
| Difference in Profit (without Labor Expense) | -$281[a] | -$212[a] | -$69 |
| Difference in Profit (Including Labor Expense) | -$235[a] | -$194[a] | -$41 |
| Difference in GWP $CO_2$ Equivalent | -16,275kg | -4,836kg | -11,439kg |
| Value of $CO_2$ to Tradeoff (without Labor Expense) | $0.017/kg | $0.044/kg | $0.006/kg |
| Value of $CO_2$ to Tradeoff (Including Labor Expense) | $0.014/kg | $0.040/kg | $0.004/kg |

[a] statistically significant at $p< 0.05$

Notes: System 1 represents the simplest pasture system including bermudagrass and ryegrass. System 2 includes a clover mix in addition to grasses in System 1, and System 3 includes sorghum sudan hybrid and soybean in addition to the forage in System 2. Currency amounts are in US$.

economically equivalent. System 2 had $41 including labor expense ($69 excluding labor expense) lower economic profit per steer than System 1, which was not statistically different, and 11,439 kg lower $CO_2$ equivalent GWP per steer than System 1. Thus, System 2 appears to dominate System 1 because it produced statistically equivalent economic profit but had lower GWP than System 1.

## 2.4. Conclusions

From a cost and returns point of view placing no economic value on carbon emissions, the least complex GFB production systems in this study, Systems 1 and 2, are more profitable than System 3. Under this scenario, there is no conclusive evidence that bermudagrass and ryegrass combinations differ in profitability from the bermudagrass, ryegrass, rye, dallisgrass, and clover mix (berseem, red and white clovers) system. These two systems were found to be more profitable than the more complex System 3 with bermudagrass, ryegrass, rye, dallisgrass and clover mix, soybean, sorghum-sudan hybrid. From a risk preference perspective, the more risk averse producers would choose System 2 while the less risk averse producers would choose System 1.

From an ecological view point considering GWP, the most complex system, System 3, is the most favorable since it produced less $CO_2$ equivalent GWP than the other two systems. System 1 produced the greatest $CO_2$ equivalent GWP. This is based on the arithmetic average of $CO_2$ equivalent emissions. Based on these results, the following trade-offs can be ascertained. If reduced $CO_2$ equivalent emissions were valued at \$0.014/kg including labor expense (or \$0.017/kg excluding labor expense), then Systems 1 and 3 would be economically equivalent. Similarly, if reduced $CO_2$ equivalent emissions were valued at \$0.040/kg including labor expense (\$0.044/kg excluding labor expense), then Systems 2 and 3 would be economically equivalent. System 2 may dominate System 1 because it produced statistically equivalent net profit and had numerically lower GWP than System 1. Similar valuations of carbon credits were conducted by Williams et al. (2004) to compare no-tillage with conventional tillage operations for 10 years. They estimated carbon credit values in the range of \$0.0086/kg to \$0.065/kg to make no till and conventional tillage operations economically equivalent. Together, these results suggest that carbon credit values of >\$0.014/kg would have the potential to entice significant change in the use of agricultural production practices.

When choosing a forage system, both profitability and GHG impacts can be considered. The findings of this study would be helpful in selecting appropriate pasture systems to fulfill the increasing demand for GFB. To understand the net carbon emissions of pasture management more thoroughly, further studies are suggested over longer time periods. Economic, social and ecological sustainability aspects should be taken into consideration when implementing extension programs for GFB production. To draw final conclusions about the selection of appropriate pasture systems, farmers must consider the complexity of management at the farm level with additional fencing and labor requirements. Since this is an experimental study within a research station, additional study at the farm level would be appropriate to evaluate its wide spread applicability. Further, a working paper by Torrico et al. (2014) found for some groups (but not others) higher sensory scores for meat produced in our most complex system, System 3. Here the higher sensory scores mean they liked System 3 beef better. This raises the question, if over time System 3 is shown to produce consistently higher sensory scores, will consumers be willing to pay premium prices for that beef such that the price for carbon would not have to be as high for producers to select System 3? This raises a rather complex question if the meats do not differ visually and do not grade differently, and should be dealt with in further research.

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# CHAPTER 3: ANALYSIS OF LABOR USE AND PROFITABILITY IN THREE PASTURE SYSTEMS FOR THE GRASS-FED BEEF PRODUCTION IN THE U.S.

## 3.1. Introduction

Labor is a major input in agricultural and livestock production. Grass-fed beef (GFB) operations are particularly labor-intensive, with labor requirements differing by production system. The major work performed by labor in a grass-fed beef operation includes moving, checking, and working animals, and operating machinery and equipment. According to USDA-NASS (2007), most beef operations in the U.S. are comparatively small, 50% of beef farms have fewer than 20 cows and operate on a fixed land area. The labor requirements of such farms are fulfilled mostly by landowners and their family members. A wide range of pasture management systems are used for GFB production throughout the U.S. with considerable differences in management complexities. Grass-fed beef production accounts for a very small share, i.e. less than 1% of the U.S. beef industry as a whole (Pelletier, Pirog, and Rasmuseen, 2010), but it has gained interest over the last two decades due to human health, environmental and animal welfare concerns (Wright, 2005, Mills, 2003; McCluskey et al., 2005). Grass-fed beef producers are interested in pasture systems that utilize less labor but yield higher profit.

Several studies have examined farm labor differences by agricultural production system. Reed et al. (2010) conducted an economic analysis of farm labor and profitability in three villages in Nepal and reported that the use of conservation systems such as strip tillage and cowpea intercropping improved the livelihoods of subsistence farmers. Gillespie et al. (2008) analyzed the roles of labor and profitability in choosing a grazing strategy for cow-calf production in the U.S. Gulf Coast Region. They found that labor requirements were higher with rotational grazing systems than with continuous grazing systems, reducing the profitability associated with rotational grazing. Wyatt et al. (2013) evaluated the effects of year-round stocking rate and stocking method on cow-calf production systems considering costs, returns and labor considerations. None of these studies have focused on grass-fed beef production. In this paper, we estimate the relative profitability of three pasture systems for grass-fed beef production with and without considering the costs associated with labor.

The specific objectives of this paper are to: 1) determine the direct costs, fixed costs, gross returns, and net returns of three pasture systems under grass-fed beef production; 2) determine the involvement of labor in specific activities in the three pasture systems; and 3) determine the most profitable pasture system for forage-fed beef production in the U.S. Gulf Coast Region considering labor and profitability.

**3.2. The Theoretical Model**

The theoretical model for this research is represented by the following profit maximizing problem for the grass-fed beef producer:

$$max\ \pi(x) = \sum_{t=1}^{T} \pi_t(X_{it})$$

$$= \sum_{t=1}^{T} \{P_{slaugh,t} * f(X_{it}) + P_{hay,t} * g[f(X_{it})] - \sum_{i=1}^{n} W_{it} * X_{it}\}, \qquad (1)$$

where: $\pi_t(.)$ is profit at year $t$, $T$ is the number of years in planning, $X_{it}$ is the amount of input $i$ used at time $t$, $P_{slaugh,t}$ is the price of a slaughter animal in year $t$, $f(X_{it})$ is the production function for a grass-fed slaughter animal, $P_{hay,t}$ is the price of hay in year t, $g[f(X_{it})]$ is the production function for hay which is a function of the production of slaughter animals, and $W_{it}$ is the price of input $i$ in year $t$. Here, the production function for hay is a function of slaughter animal production; the primary purpose of growing and maintaining pasture for forage-fed beef production is to produce beef, not hay. Since the primary purpose of growing forages is for grazing animals, only the left-over or excess forage is generally used to produce hay, which is in turn generally fed during periods of low grazing potential. Left-over hay after feeding animals is sold.

By taking the first order conditions, the optimum quantity of input $j$ for profit maximization can be estimated as follows:

$$\sum_{t=1}^{T}\{P_{slaugh,t} * \partial f(X_{it})/\partial X_j + P_{hay,t} * \frac{\partial g[f(X_{it})]}{\partial X_j}\} = \sum_{t=1}^{T} W_{it}, \qquad (2)$$

where the left hand side value represents the marginal value product and the right hand side represents the marginal factor cost, showing that the profit-maximizing producer determines optimal input usage by considering the marginal physical productivity, output prices, and input prices. In the case of using multiple forage species for pasture and/or hay, additional labor costs will be incurred if the additional value of the product (finished animals and hay) is greater than the additional cost associated with the labor input.

If extensive data were available, solving the profit-maximizing problem using the production function could provide the optimum level of input usage. It is difficult, however, to find such extensive data from experimental research, making it impossible to estimate the optimum input-output combination based on the above theoretical model. However, optimal solutions can be approximated at discrete points in the production function. In this study, comparisons were made between three different pasture combinations evaluating direct expenses including labor involvement for different activities, fixed expenses, steer income, hay income, and net return associated with each system.

### 3.3. Data and Empirical Methods

Three treatments used in a field experiment at the LSU AgCenter Iberia Research Station (IRS) in Jeanerette, LA, from 2009-2010 to 2013-2014 represented pasture systems with different degree of management complexity. The three forage systems were: (1) bermudagrass as summer pasture, annual ryegrass as winter pasture; (2) bermudagrass as summer pasture, annual ryegrass, rye, and clover mix (berseem, red, and white clovers) as winter pastures; and (3) bermudagrass, sorghum-sudan hybrid, and forage soybean as summer pastures, and annual ryegrass, rye, clover mix (berseem, red, and white clovers), and dallisgrass as winter pastures. These systems were chosen as representative of the types of systems currently being used for grass-fed beef producers in the U.S. Gulf Coast Region (Scaglia et al., 2014). The pasture systems differ from each other in terms of management complexity. System 1 consists of only two forage types and it is the simplest system while System 3 consists of nine forage types and it is the most complex among these systems.

System 1 consists of 3 sub-paddocks of bermudagrass, System 2 consists of 2 sub-paddocks of bermudagrass, and System 3 consists of only one bermudagrass paddock. Since Systems 2 and 3 includes other forages, System 1 included the highest number of bermudagrass sub-paddocks. These sub-paddocks were divided using temporary fencing as per the availability of green forages and management of grazing.

Annually, 54 seven to eight month old Fall-born steers were assigned to one of the three pasture systems immediately after weaning and remained until time of harvest at age 17-19 months. The same pastures were used for each treatment each year. The experimental year began in May and ended by the end of April the following year. The three forage systems were managed in different sub-paddocks at the IRS, and animals were rotated among the sub-paddocks based on forage availability. The steers were blocked at weaning by weight into nine groups (six steers/group). Each group was randomly assigned to one of the three treatments, each of which was replicated three times. During the transition period when forage availability was low (mid-November to December), animals were fed hay produced in the paddocks allocated to the system/ replication group. Constructed portable shades were made available for the animals in each group. They were moved along with the animals when rotated. Water and mineral mix were available at all times. The stocking rate was one hectare per animal for each entire system.

Detailed cost and input records were kept for each pasture by year. These records were used to develop detailed cost and return estimates for each treatment/replication. Budgets included returns, direct expenses, fixed expenses, and land rent. Expenses for seed, fertilizer, pesticide, minerals, medication, twine, fuel, purchased weaned steers, repair and maintenance of machinery, and interest on operating capital were included in the direct expenses. Depreciation and interest on machinery (trucks, tractors, and other implements), permanent fencing, and temporary fencing were included in the fixed expenses. The fixed costs of machinery and equipment were allocated according to use, assuming their useful life and performance rates as shown in Boucher and Gillespie (2009, 2010, 2011, 2012, and 2013). The opportunity cost of land rental was included. Similarly, labor used for each activity was kept by pasture system. A total of 45 cost and returns estimates were made for the project: (3 treatments $^{x}$ 3 replications $^{x}$ 5 years).

For the analysis of labor, labor usage was categorized into the following four subgroups. Moving Animals and Shades involved all activities including measuring the availability of forage and movement of animals as per the availability of forages in the different paddocks within the same pasture system. It also included the movement of shades and water troughs. The second category was Checking Animals and Routine Tasks**,** which included checking animals twice per day Monday-Friday and once per day during the weekend. On days the animals were moved, the checking task was conducted at the same time. Therefore, no separate labor was required for this task on the animal moving day. Another category of labor was for Vaccinating Animals. This was done as per vaccination requirements. The labor required for moving and vaccinating animals was included in this category. The final category of labor was Operator Labor**,** which included the operator labor for all machinery as well as labor involved in the repair and maintenance activities. Previous work examining labor use by stocking strategy includes Gillespie et al. (2008) and Wyatt et al. (2013).

The fifth year data differed somewhat from that of previous years because berseem clover was not available in the local market that year. Furthermore, sorghum-sudan was not available, but was replaced with pearl millet in the 5$^{th}$ year. In addition, there was a labor shortage at the IRS. Therefore, application of fertilizer and moving of animals were conducted only two-thirds of the times of the earlier years. Thus, input use differed and was somewhat lower in the fifth year. We included fifth-year data, however, since those conditions sometimes prevail in actual farm situations. Thus, analysis including the fifth-year data can reflect the reality of resource constraints on a farm. Annual input and output prices are presented in Table 3.1. With the exception of those listed in subsequent discussion, these prices were those used by Boucher and Gillespie (2009, 2010, 2011, 2012, and 2013) in cost and return estimates for cattle and forage production. The

Table 3.1. Prices of Inputs and Outputs for the Experimental Years

| Inputs/Outputs | Unit | Price in $ | | | | |
|---|---|---|---|---|---|---|
| | | 2009 | 2010 | 2011 | 2012 | 2013 |
| Urea | lb | 0.18 | 0.16 | 0.19 | 0.19 | 0.28 |
| Gramoxone Max | pt | 4.97 | 5.46 | 5.46 | 5.46 | 5.46 |
| Grazon P+D | pt | 4.01 | 4.94 | 3.87 | 4.16 | 4.23 |
| Outrider | onz | 20.00 | N/A | N/A | N/A | N/A |
| Roundup Original Max | pt | 6.56 | 7.25 | 7.20 | 6.08 | 6.00 |
| Malathion | pt | N/A | 4.25 | 4.23 | 4.23 | N/A |
| Sevin 80% WP | lb | 6.13 | 6.81 | 7.35 | 7.35 | 7.35 |
| Bovishield | dose | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| One Shot | dose | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Sweetlix | block | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 |
| Ultrabac 8 | dose | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Vigortone 3V2 | bag | 26.20 | 26.20 | 26.20 | 26.20 | 26.20 |
| Vigortone 3V5 | bag | 17.13 | 17.13 | 17.13 | 17.13 | 17.13 |
| Weaning Calf | cwt | 98.30 | 114.00 | 114.00 | 125.00 | 150.00 |
| Twine | ton | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| Berseem Clover Seed | lb | 2.14 | 2.15 | 3.50 | 3.50 | N/A |
| Red Clover Seed | lb | 2.50 | 3.00 | 1.20 | 1.20 | 1.80 |
| White Clover Seed | lb | 2.50 | 3.20 | 3.10 | 3.00 | 3.00 |
| Rye Seed | lb | 0.22 | 0.44 | 0.44 | 0.45 | 0.50 |
| Ryegrass Seed | lb | 0.61 | 0.70 | 0.50 | 0.48 | 0.50 |
| Cowpea Seed | lb | N/A | N/A | N/A | 1.00 | 1.00 |
| Soybeans Seed | lb | 0.56 | 0.53 | 0.60 | 0.60 | 0.60 |
| Sorghum Sudan Seed | lb | 0.47 | 0.80 | 0.80 | 0.84 | N/A |
| Pearl Millet | lb | N/A | N/A | N/A | N/A | 1.40 |
| Hay* | bale | 45.00 | 40.00 | 82.50 | 37.50 | 40.00 |
| Steers at Harvest* | cwt | 116.00 | 133.00 | 141.00 | 147.00 | 168.00 |
| Diesel Fuel | gallon | 2.20 | 2.30 | 2.75 | 3.50 | 3.31 |

* Although the prices of hay and steer at harvest were tabulated as 2009, 2010, 2011, 2012, and 2013, those were based on USDA prices in the following years (2010, 2011, 2012, 2013, and 2014) since the harvesting and selling of hay and steers was in the second calendar year of the experiment.

Note: N/A indicates data not available.

prices of weaned calves were taken from 2011 Louisiana Agricultural Statistics (LSU Agricultural Center, USDA-NASS, 2012) for the first three years. The last two years are based on the Boucher Gillespie (2012, 2013) cost and returns estimates due to the unavailability of Louisiana Agricultural Statistics data for those years. Hay was measured as large bale of an average weight of 430kg. We used the Weekly Texas Hay Report for hay prices (USDA-TX, 2010, 2011, 2012, 2013, and 2014). The price of hay was at its peak, i.e. $82.50 per large round bale, in 2012 due to unfavorable weather and low hay production in that particular year. The price of hay was approximately double that of the preceding and succeeding years. We used the USDA-ERS (2014) published prices for fed steers as a base, adjusted for the grass-fed steer price by adding $0.44/kg as suggested by the manager of one of the larger grass-fed beef production firms in the Gulf Coast Region.

Annual fixed costs and the repair and maintenance cost of fixed inputs are presented in the Table 3.2. Fixed costs of machinery and equipment are determined using capital recovery method (Boehje and Eidman, 1984). Annual capital recovery is calculated using the following equation:

Annual Capital Recovery Charge = {(Purchase Price- Salvage Value)*Capital Recovery Factor}
+ (Salvage Value*Interest Rate)

The capital recovery factor is the tabulated value based on the useful life of equipment in years and the interest rate in percentage. The fixed cost per hour is calculated by dividing the annual capital recovery charge by annual hourly use. Similarly, the direct cost per hour is estimated by computing the total repair and maintenance costs over the life of machinery and dividing by total hours of use of the machinery.

Table 3.2. Prices of Fixed Inputs, Machinery, and Equipment

| Fixed Input Annual Costs in US$ | | | |
|---|---|---|---|
| Input Structure | Units | Repair and Maintenance | Fixed costs |
| Fence Electric | km | 23.61 | 156.19 |
| Fence 5 wire | km | 130.49 | 302.30 |
| hay rack | each | 9.04 | 26.27 |
| Shade structure | each | 3.48 | 72.65 |
| Shade cloth | each | 5.30 | 64.25 |
| Water tank and pump | each | 40.00 | 132.50 |
| Machinery and Equipment Costs in US$ | | | |
| Machinery/Equipment | | Direct Costs/ hour | Fixed Costs/hour |
| Mower Conditioner | | 10.79 | 12.89 |
| Hay Rake | | 2.43 | 3.16 |
| Hay Tedder | | 2.45 | 3.67 |
| Hay Fork | | 0.09 | 0.22 |
| Baler Round | | 13.98 | 18.56 |
| Mower Drum | | 4.68 | 5.59 |
| Boom Sprayer | | 2.35 | 3.12 |
| Tractor (40-59hp) | | 6.48 | 4.42 |
| Tractor (60-89hp) | | 10.05 | 7.81 |
| Tractor (90-115hp) | | 14.31 | 12.52 |

Net returns, fixed costs, direct costs, labor use, steer returns, and hay returns were estimated. Similarly, differences in the labor involved in each of the four labor categories were also estimated. Differences were determined using the Kenward-Roger Degrees of Freedommethod (Kenward and Roger, 1997).

Since this research analysis is based on only 5 years of data, i.e. 45 observations, simulation and dominance techniques were used to strengthen the analysis. Simetar, a commercial mathematical simulation software developed by Richardson et al. (2008), was used to develop 1,000 randomly simulated input (fertilizer, fuel, and calves) and output (steers, hay) prices developed based on historical data (13 years; 2001-2013). Hay yield was estimated based on 13 years of historical rainfall data at the IRS and 1,000 randomly simulated values were developed from the same software. We did not observe significant variation in the other input variables and other prices and quantities of steers, so these were taken as constant for this analysis. Based on these simulated values and constant values, 1,000 net returns for each of the systems were developed.

Certainty equivalents (CE) were estimated assuming different risk aversion coefficients using the 1,000 simulated net returns for each system as per the relationship outlined by Hardakar et al. (2004). The CE is defined as the net return value held with certainty at which the decision maker would be indifferent to a risky distribution of net return values. The utility function of the decision maker is used to estimate the CE. The relationship between the utility function *U(w)* and the absolute risk aversion coefficient, $r_a(w)$ is shown in equation (1):

(1) $$U(w) = -exp(-r_a(w)),$$

where *w* is the wealth or income associated with the choice. Equation (2) defines the absolute risk aversion coefficient as the negative ratio of the second and first derivatives of the utility function:

(2) $$r_a(w) = -\frac{u''(w)}{u'(w)}\,.$$

The relationship between the absolute risk aversion coefficient and the relative risk aversion coefficient, $r_r(w)$, is expressed as:

(3) $$r_a(w) = r_r(w)/w.$$

The CE for a random sample of size *n* from risky alternatives *w* is estimated as follows, as shown by Hardaker et al. (2004):

(4) $$CE\big(w, r_a(w)\big) = ln\left\{\left(\frac{1}{n}\sum_i^n exp(-r_a(w)w_i)\right)^{-1/r_a(w)}\right\}.$$

A general classification of relative risk aversion coefficients falling in the range of 0 for risk neutral to 4 for highly risk averse was proposed by Anderson and Dillon (1992). Absolute risk aversion coefficients were obtained by dividing a range of relative risk aversion coefficients (0 to 4) by the estimated mean net return. This gives the maximum absolute risk aversion coefficient of 0.0024, which is used in a stochastic efficiency with respect to function (SERF) analysis. SERF provides a means to evaluate the risky alternatives in terms of CEs for a specified range of absolute risk aversion coefficients. The result is graphed to analyze the dominance by system.

### 3.4. Results and Discussion

Revenue and expenses per steer excluding labor are presented in Table 3.3. Mean steer incomes were $1,434.42, $1,445.68, and $1,440.78 for Systems 1, 2, and 3, respectively, which did not differ significantly at $p \leq 0.10$ among the systems. Mean weights per steer per year were 462 kg, 461 kg, and 464 kg, respectively, for Systems 1, 2, and 3 (Table 3.4).

Hay incomes were $667.51, $527.24, and $350.91 for Systems 1, 2, and 3, respectively, which differed among these systems. Hay was made from surplus green forage after grazing the animals. Of the hay produced, part of it was fed to the steers of the respective systems during the lean season of the fall when green forages were not available. Left-over hay was sold, constituting the hay income. System 1 yielded the highest hay income while System 3 yielded the lowest, as more hay was harvested in System 1 than System 2 and more harvested in System 2 than in System 3. Hay produced and hay consumed within systems are shown in Table 3.4. The average hay amounts produced per year per system were 87, 70, and 49 bales, respectively in Systems 1, 2, and 3. The average hay consumption amounts per groups of 6 steers were 5, 5, and 6 bales for Systems

Table 3.3. Revenue, Expenses, and Return over Expenses (Without Labor Included), per Animal Basis

| Revenue / Expenses | System 1 | System 2 | System 3 |
|---|---|---|---|
| Total Revenue | 2,109.94$^{c}$ | 1,972.93$^{c}$ | 1,791.70$^{ab}$ |
| Steer Income | 1,434.42 | 1,445.68 | 1,440.78 |
| Hay Income | 667.5$^{bc}$ | 527.24$^{ca}$ | 350.91$^{ab}$ |
| Direct Expenses | 1,275.68 | 1,264.27 | 1,279.27 |
| Fertilizer Expense | 293.48$^{bc}$ | 230.44$^{ca}$ | 195.73$^{ab}$ |
| Pesticide Expense | 39.47$^{c}$ | 37.67$^{c}$ | 48.02$^{ab}$ |
| Livestock Expense | 690.77 | 690.54 | 692.61 |
| Seed Expense | 55.08$^{bc}$ | 134.46$^{ca}$ | 188.34$^{ab}$ |
| Twine Expense | 3.44$^{bc}$ | 2.52$^{ca}$ | 2.01$^{ab}$ |
| Medication, Mineral Expense | 22.17 | 22.67 | 22.67 |
| Diesel Expense | 68.22$^{bc}$ | 55.14$^{ca}$ | 43.27$^{ab}$ |
| Repair Maintenance Expense | 59.72$^{bc}$ | 48.54$^{ca}$ | 41.10$^{ab}$ |
| Interest Expense | 42.72 | 46.68 | 41.82 |
| Return over Direct Expenses | 826.19$^{c}$ | 708.60$^{c}$ | 512.34$^{ab}$ |
| Fixed Expenses | 198.03$^{bc}$ | 158.82$^{ac}$ | 135.03$^{ab}$ |
| Total Specified Expenses | 1,473.73$^{c}$ | 1,423.20 | 1,414.42$^{a}$ |
| Return over Specified Expenses | 628.08$^{c}$ | 549.68$^{c}$ | 377.18$^{ab}$ |
| Residual Income | 545.70$^{c}$ | 457.58$^{c}$ | 305.09$^{ab}$ |

Note: Superscript a means differ significantly from System 1, superscript b means differ significantly from System 2, and superscript c means differ significantly from System 3 within rows at $p<0.10$

Residual Return = Total Income - Direct Expense - Fixed Expense - Land Rent

Table 3.4. Steer and Hay Measures

| | Average Weight per Steer in Kg | | Number of Hay Bales | |
|---|---|---|---|---|
| System | Initial | Final | Produced | Fed |
| System 1 Average | 260 | 462 | 87 | 5 |
| 2009 | 255 | 461 | 54 | 7 |
| 2010 | 247 | 459 | 148 | 4 |
| 2011 | 273 | 466 | 86 | 6 |
| 2012 | 260 | 472 | 89 | 4 |
| 2013 | 266 | 451 | 59 | 4 |
| System 2 Average | 260 | 461 | 70 | 5 |
| 2009 | 258 | 445 | 81 | 7 |
| 2010 | 246 | 469 | 101 | 3 |
| 2011 | 275 | 459 | 58 | 4 |
| 2012 | 260 | 474 | 68 | 4 |
| 2013 | 263 | 460 | 42 | 5 |
| System 3 Average | 261 | 464 | 49 | 6 |
| 2009 | 256 | 440 | 64 | 6 |
| 2010 | 247 | 463 | 73 | 5 |
| 2011 | 275 | 474 | 40 | 5 |
| 2012 | 259 | 482 | 37 | 6 |
| 2013 | 266 | 461 | 29 | 8 |

1, 2, and 3, respectively. Total incomes per steer per year were $2,109.94, $1,972.93 and $1,791.70 for Systems 1, 2, and 3, respectively. Systems 1 and 2 had higher total income than System 3. The major income determinant by system was hay production.

Direct expenses included seed, fertilizer, pesticides, weanling animals, minerals, vaccinations, diesel, repair and maintenance, and interest on operating capital. Fertilizer expense differed among systems with the highest expense in System 1 and the lowest expense in System 3. This was due to the inclusion of leguminous nitrogen-fixing forages in Systems 2 and 3. System 3 included more leguminous forages than System 2; therefore, System 3 required less fertilizer expense than System 2. Seed expenses were greatest in System 3 because it included more forage types than the other two systems. Seed expense in System 1 was the lowest because it included only bermudagrass and ryegrass. Similarly, diesel and repair and maintenance expenses differed among systems because of different levels of machinery and equipment use for harvesting hay in the different systems. Since System 1 produced more hay, the machinery use was greatest in System 1. Therefore, machinery expenses were greater in System 1 than in Systems 2 and 3.

Overall, direct costs excluding labor were \$1,275.68, \$1,264.27, and \$1,279.27 for Systems 1, 2, and 3, respectively, which did not differ statistically at $p \leq 0.10$ among the systems. Although fertilizer cost was greater in System 1 than in Systems 2 and 3 and seed cost was greater in System 3 than in Systems 1 and 2, the total direct cost did not differ statistically among the systems. The return over direct costs is the total revenue minus the direct costs. System 3 yielded less return over direct expense than Systems 1 and 2.

Fixed expenses differed among systems due mostly to the differences in the use of machinery and equipment for cutting and baling hay. Total specified expenses include both direct and fixed expenses. Return over specified expenses is estimated by subtracting total specified expenses from total income. Again, System 3 yielded lower return over total specified expenses than Systems 1 and 2. Residual return was estimated after subtracting total specified expenses and an opportunity cost of land from the total income. The residual incomes were \$546, \$458, and \$309, respectively, for Systems 1, 2, and 3 with Systems 1 and 2 having higher residual income than System 3.

Labor involvement in the 3 systems is presented in Table 3.5. In total, 16.89, 14.55, and 13.15 hours of labor per animal were involved annually in the different activities in Systems 1, 2, and 3, respectively. Higher labor involvement in System 1 was due to the higher use of machinery for harvesting and making hay. Similarly, the movement of animals was greatest in System 1 and

Table 3.5. Annual Labor Usage Hours in the Different Systems, per Animal

| Labor Category | System 1 | System 2 | System 3 |
|---|---|---|---|
| Moving Animals and Shades | $4.26^{bc}$ | $3.87^{ca}$ | $3.42^{ab}$ |
| Checking and Routine Tasks | $2.93^{c}$ | $2.97^{c}$ | $3.02^{ab}$ |
| Vaccinating Animals | 0.37 | 0.37 | 0.37 |
| Operator Labor | $9.33^{bc}$ | $7.35^{ac}$ | $6.34^{ab}$ |
| Total labor | $16.89^{bc}$ | $14.55^{ac}$ | $13.15^{ab}$ |

Note: Superscript a means differ significantly from System 1, superscript b means differ significantly from System 2, and superscript c means differ significantly from System 3 within rows at $p<0.10$

least in System 3, which was due to more movement among the sub-paddocks than the movement of animals between paddocks. Since bermudagrass sub-paddocks were many in System 1, each of which was further divided into 5 smaller sub-paddocks, the movements within sub-paddocks were greater within bermudagrass paddocks than among other forage paddocks. The labor involved in vaccinating animals did not differ as all systems were treated the same in this regard. Although labor involved in checking animals and routine tasks should generally be the same across the different systems, it differed among the systems because checking animals was conducted at the same time as moving animals on the days animals were moved. More than 50% of the total labor involved was operator labor. Movement of animals was the second-most labor-consuming activity, while vaccinating was the least labor-consuming activity.

The results of cost and returns analysis including labor expenses are presented in Table 3.6. Labor expenses are divided into operator labor and other. Total labor expenses were \$160, \$138, and \$123 for Systems 1, 2, and 3, respectively, which differed among the systems. Operator labor expenses were greatest in System 1 due to the higher use of machinery and equipment for

Table 3.6. Revenue, Expenses, and Return over Expenses (Labor $9.60/hr. Included), per Animal Basis

| Revenue / Expenses | System 1 | System 2 | System 3 |
|---|---|---|---|
| Total Revenue | 2,109.94$^{c}$ | 1,972.93$^{c}$ | 1,791.70$^{ab}$ |
| Steer Income | 1,434.42 | 1,445.68 | 1,440.78 |
| Hay Income | 667.5$^{bc}$ | 527.24$^{ca}$ | 350.91$^{ab}$ |
| Direct Expenses | 1,442.06 | 1,408.67 | 1,406.52 |
| Fertilizer Expense | 293.48$^{bc}$ | 230.44$^{ca}$ | 195.73$^{ab}$ |
| Pesticide Expense | 39.47$^{c}$ | 37.67$^{c}$ | 48.02$^{ab}$ |
| Livestock Expense | 690.77 | 690.54 | 692.61 |
| Seed Expense | 55.08$^{bc}$ | 134.46$^{ca}$ | 188.34$^{ab}$ |
| Twine Expense | 3.44$^{bc}$ | 2.52$^{ca}$ | 2.01$^{ab}$ |
| Medication, Mineral Expense | 22.17 | 22.67 | 22.67 |
| Labor Expense | 70.57$^{bc}$ | 67.21$^{ca}$ | 62.29$^{ab}$ |
| Operator Labor Expense | 89.60$^{bc}$ | 70.52$^{ca}$ | 60.91$^{ab}$ |
| Diesel Expense | 68.22$^{bc}$ | 55.14$^{ca}$ | 43.27$^{ab}$ |
| Repair Maintenance Expense | 59.72$^{bc}$ | 48.54$^{ca}$ | 41.10$^{ab}$ |
| Interest Expense | 48.40 | 49.82 | 46.26 |
| Return over Direct Expenses | 660.51$^{c}$ | 564.19$^{c}$ | 385.08$^{ab}$ |
| Fixed Expenses | 198.03$^{bc}$ | 158.82$^{ac}$ | 135.03$^{ab}$ |
| Total Specified Expenses | 1,639.17$^{bc}$ | 1,567.59$^{a}$ | 1,541.79$^{a}$ |
| Return over Specified Expenses | 463.04$^{c}$ | 405.27$^{c}$ | 249.87$^{ab}$ |
| Residual Income | 380.70$^{c}$ | 331.02$^{c}$ | 177.72$^{ab}$ |

Note: Superscript a means differ significantly from System 1, superscript b means differ significantly from System 2, and superscript c means differ significantly from System 3 within rows at $p<0.10$

Residual Return = Total Income - Direct Expense - Fixed Expense - Land Rent harvesting and baling hay. Other labor expenses were also greatest in System 1 and least in System 3 due to greater movement of animals in System 1 and the least in System 3. Returns over direct expenses were \$826.19, \$708.60, and \$512.34 for Systems 1, 2, and 3, respectively, without accounting for the labor costs. System 3 had a lower return over direct cost than Systems 1 and 2. The returns over direct expenses when including labor costs were reduced to \$660.51, \$564.19, and \$385.08 for Systems 1, 2, and 3, respectively. Again, System 3 had a lower return over direct cost than the other systems, as shown in Table 3.6. Though labor used in System 1 was greater than that for the other systems, System 1 remained the most profitable of the systems.

System 1 had greater total specified expenses than Systems 2 and 3. Return over total specified expenses was lowest in System 3 while Systems 1 and 2 did not differ statistically from each other. After accounting for labor, the residual returns were \$380.72, \$331.02, and \$177.72 for Systems 1, 2, and 3, respectively. Similar to the results without including labor expenses, the residual returns of Systems 1 and 2 were greater than that with System 3 after accounting labor. There was no statistical difference in the residual return between Systems 1 and 2 although System 1 yielded numerically higher income than System 2.

Sensitivity analysis showed that if the wage rate for the labor were greater than \$32 per hour, System 2 would be numerically more profitable than System 1. In all cases, Systems 1 and 2 dominated System 3. Results of the simulation and stochastic efficiency analysis are presented in Figures 3.1 and 3.2. Figure 3.1 shows the stochastic efficiency with respect to a function without including labor. It clearly shows that System 1 dominates Systems 2 and 3 at all levels of risk aversion, though the margin of dominance narrows when the risk aversion coefficient becomes larger as shown in the figure. Cost and returns analysis did not show that Systems 1 and

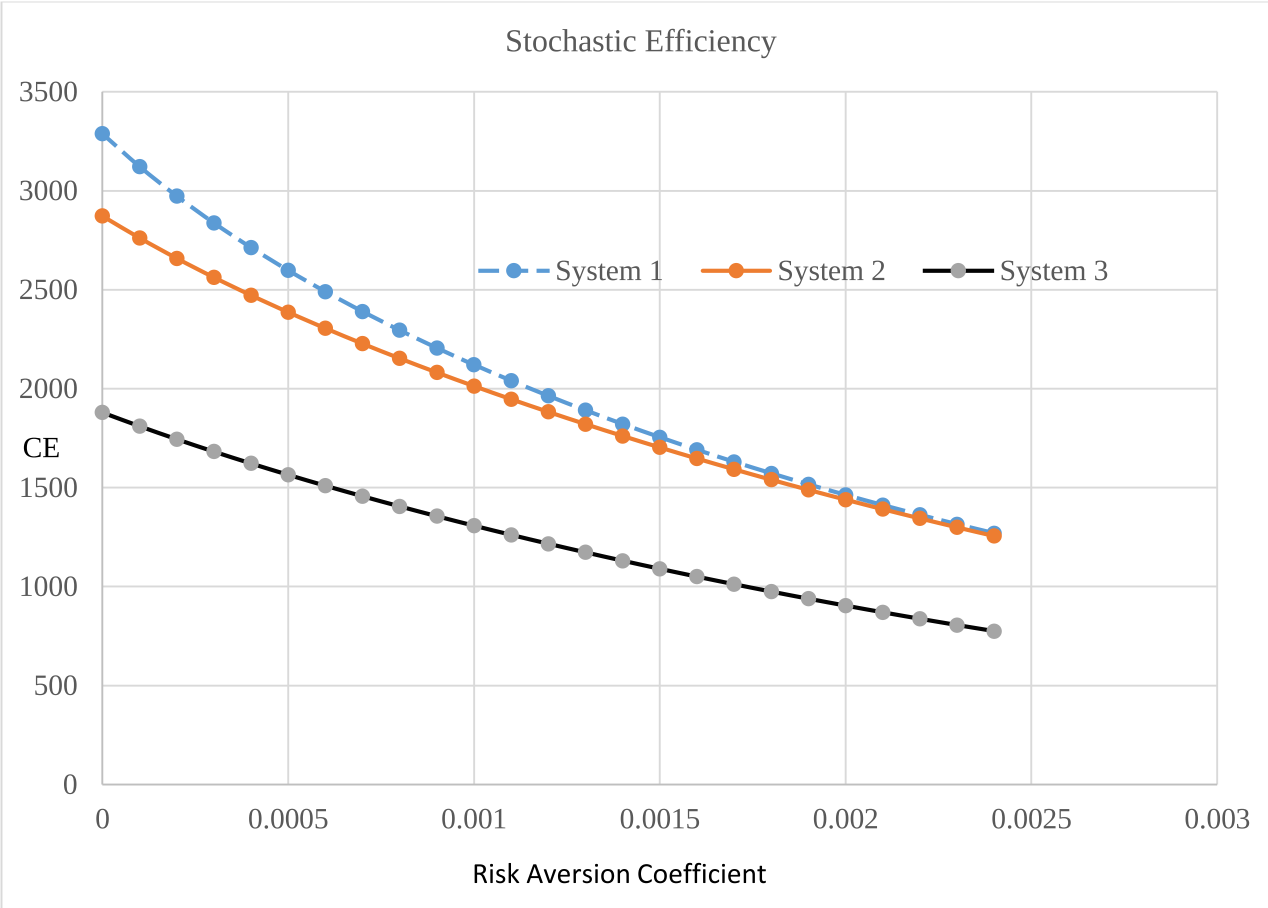


Figure 3.1. Stochastic Efficiency without Labor

2 differed statistically. However, results of the simulation and dominance analysis clearly show that System 1 dominates both Systems 2 and 3. Furthermore, both Systems 1 and 2 dominate System 3. The findings from the cost and returns analysis did not show a statistically significant difference between Systems 1 and 2, but when assuming the farmers were risk averse, System 1 dominated System 2.

The situation changes when labor is included in the profitability estimates (Figure 3.2). In all cases, Systems 1 and 2 dominate System 3. With risk aversion coefficients of <0.0008, System 1 dominates System 2, but when risk aversion coefficients are >0.0008, System 2

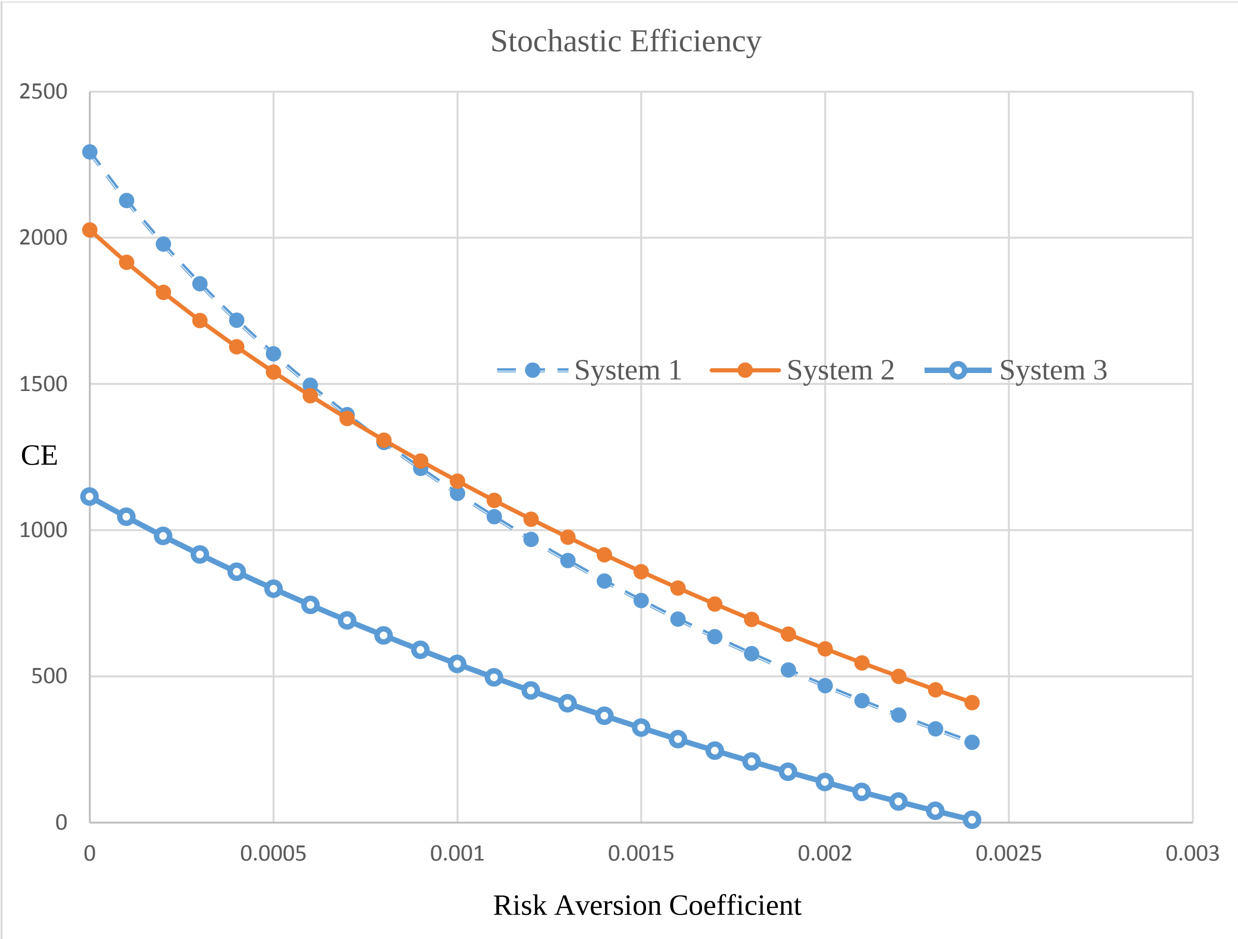


Figure 3.2. Stochastic Efficiency with Labor

dominates System 1. The coefficient of absolute risk aversion is a relative term and its interpretation is also relative. Thus, the producer would make his or her decision among Systems 1 and 2 based on his/ her risk preference. There was relatively higher variability of hay production in System 1 than in System 2, thus its higher level of production risk. Since the difference in residual returns without accounting for labor was wider, System 1 dominated System 2 in the former case.

### 3.5. Conclusions

Without accounting for labor, Systems 1 and 2 were more profitable than System 3. Under this condition, there is no conclusive evidence that the burmudagrass and ryegrass combination system differs in profitability from the bermudagrass, ryegrass, rye, dallisgrass and clover mix (berseem, red, and white clover) system. When accounting for labor, Systems 1 and 2 were again more profitable than System 3, with no significant difference between Systems 1 and 2. Though many farm operations are run by household members, accounting for the value of labor has a significant impact on the net farm return.

System 1 was more profitable and more labor-consuming because of the higher use of machinery for hay making and harvesting. Therefore, there was less difference in the residual return among the various systems after accounting for labor. Since System 1 consists of bermudagrass and ryegrass, it is the simplest system in the context of management complexity.

On one hand, results of simulation and stochastic efficiency analysis further confirm the results of the cost and returns analysis. In both cases, with or without including labor inputs, Systems 1 and 2 dominate System 3. However, due to the narrower numeric difference in profitability after accounting labor, the choice between Systems 1 and 2 changed based on the risk aversion of the decision makers. The price of labor would have to be $32 or more before System 2 would become numerically more profitable holding all else equal.

If we were to consider, however, the carbon dioxide equivalent emissions from these systems, System 2 would emits lower than System 1 (Bhandari et al. 2013). System 3 had the lowest carbon dioxide equivalent emissions. Furthermore, Torrico et al. (2014) analyzed sensory scores for the meats from the three systems and found higher sensory scores for System 3 by some groups. These results raise further concerns in determining the profitability of different systems. Further investigation on carbon emissions and the value of carbon reduction as well as premium received for superior meat products would be needed to develop a wholisitic evaluation of the economics of those systems.

The findings of this study are useful in the context of developing a GFB production program in the Southeastern U.S. Since the results are based on experimental data from a research station where conditions are relatively controlled, there might be some variation in their wider application. Similar research can be replicated in other regions of the country to determine the appropriate pasture system for that particular region.

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# CHAPTER 4: EFFICIENCY OF GRASS-FED BEEF PRODUCTION IN THE U.S.

## 4.1. Introduction

Grass-fed beef (GFB) production has experienced increased research and development attention over the last two decades due to human health, environmental, animal welfare, and sustainability perspectives (Wright, 2005; Mills, 2003; McCluskey et al., 2005). As per Gwin (2009), U.S. GFB production in 2008 was estimated at 50,000 to 100,000 head, which accounted for less than 0.5% of the total U.S. beef produced. Pelletier, Pirog, and Rasmuseen (2010) reported that the share of GFB production was less than 1% of the total beef industry. Various consumer surveys, however, have reported that there are 20-30% of U.S. beef consumers who are willing to pay premium prices for GFB (Umberger et al., 2002; Cox et al., 2006) and the U.S. imports GFB from New Zealand and Australia (Umberger, Boxall, and Lacy, 2009; USDA ERS, 2015). Thus, it appears the GFB industry has growth potential and existing grass-fed beef producers are interested to know how their operations can be made more efficient. We are unaware of any previous studies that have focused on the efficiency of GFB operations. The present study evaluates productivity measures of GFB production and the variables that influence production efficiency in GFB operations.

The U.S. beef industry is the second largest U.S. agricultural industry, the largest fed-cattle industry in the world, and the world's largest producer of beef (USDA, ERS, 2012). As per USDA's projections (USDA, Agricultural Projections, 2014), overall beef production is forecast to increase through 2020 after decreased production over the last 15 years (Figure 1.1). Alternative beef production which includes organic, natural, and grass-fed beef constitutes about 3% of the total beef market and has grown about 20% per year in recent years despite total U.S.

beef production decreasing for the last few years (Mathews and Johnson, 2013).

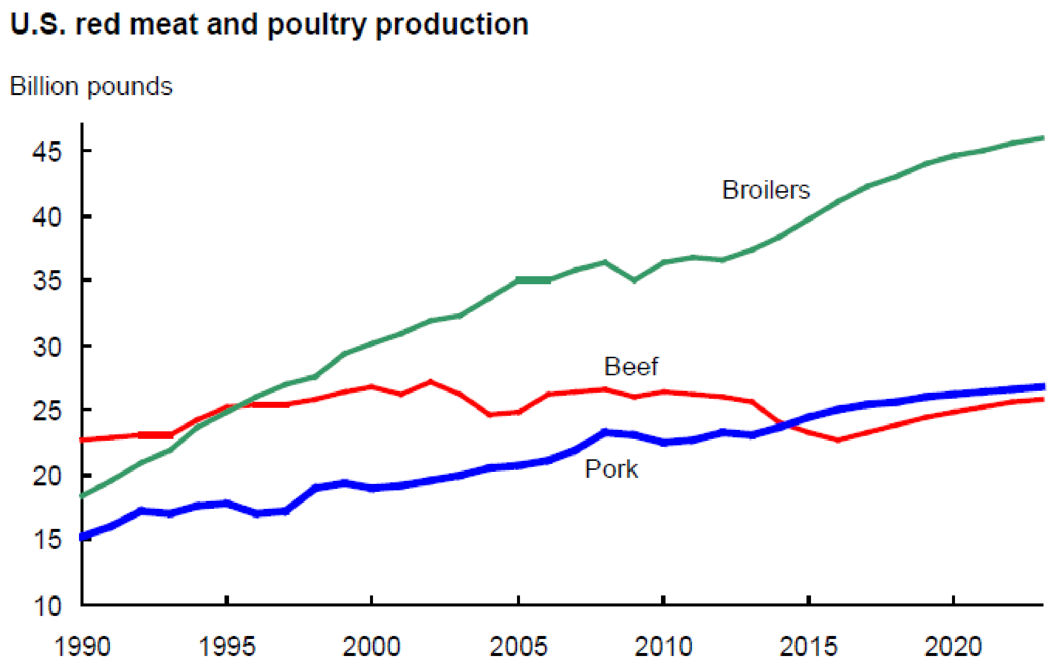


Figure 4.1. U.S. Red Meat and Poultry Production
Data Source: USDA Agricultural Projections, February, 2014. Long-term Projections to 2023

A number of previous studies have addressed production efficiency issues in U.S. agriculture. Morrison-Paul et al. (2004) studied scale economies and efficiency in U.S. agriculture using deterministic and stochastic frontier methods, finding that some small family farms were both scale and technically inefficient. They found that farm size was a driving factor to achieve scale and scope economies. Numerous studies have evaluated technical and economic efficiency of various crop and livestock enterprises (Fleming et al., 2010; Asadullah and Rahman, 2009; Rakipova, Gillespie and Franke, 2003; Nehring et al., 2012). Wadud and White (2000) evaluated technical efficiency estimates using the data envelopment analysis (DEA) method on farm level data in Bangladesh and found that environmental degradation and irrigation infrastructure had major influences on technical efficiency. Comparing the technical efficiency of organic and non-organic dairy farms, Mayen, Balagtas, and Alexander (2010) rejected the homogeneous technology hypothesis and found that organic farms were approximately 13% less productive than non-organic farms. A stochastic frontier model using a translog production function was used by Krasachat (2008) to measure the technical efficiency of feedlot cattle farms in Thailand. Krasachat (2008) found that education, experience, number of farm visits, and farm size had positive influences on farm technical efficiency while producer age and variations in cattle breed had no significant effects on technical efficiency. Otieno, Hubbard, and Ruto (2012) analyzed the technical efficiency of beef production in Kenya and found the average technical efficiency to be 69%.

Samarajeewa et al. (2012) analyzed the production efficiency of beef cow/calf farms in Alberta, Canada. They used the Cobb-Douglas functional form to represent cow-calf farm technology. They reported that technical, allocative, and economic efficiencies were 83%, 78% and 67%, respectively. Thus, technical efficiency analysis has been used for various agricultural commodities including the fed cattle industry. We are unaware of any technical and economic efficiency studies analyzing GFB production.

The overall objective of this paper is to determine the technical efficiency and productivity of U.S. GFB production. The specific objectives are to:

- Determine the cost of production of U.S. GFB farms.
- Determine the distribution of technical efficiencies of U.S. GFB farms.
- Determine the returns to scale of U.S. GFB farms.
- Determine the effects of farm specialization, farm size, and farmer demographics on the technical efficiency of U.S. GFB farms.

## 4.2. Data

A list of U.S. GFB producers was collected from online sources such as www.eatwild.com, the American Grass-fed Association, MarketMaker, and general Google searches for GFB farms. A total of 1,050 GFB producers' names and addresses were collected. A cost and returns survey was conducted with U.S. GFB producers during the Fall of 2013. This survey was the follow-up of an earlier survey which had collected information on technology and marketing decisions of these producers, as well as farm descriptors and farmer demographics and perceptions of goals and challenges facing the industry. The first 10-page survey was extensive, including the following nine different sections: general farm operation information, breeding and other management practices, selection of animals for grass finishing, pasture and grazing management for the GFB operation, reasons for selecting the GFB enterprise, goal structure, marketing, important challenges faced by GFB producers, and demographic and financial information. The first survey questionnaire is presented in Appendix A.

In the first survey, conducted during August and September, 2013, questionnaires were sent using Dillman, Smith, and Christian's (2009) Tailored Design Method, with four contacts including a personally addressed letter and questionnaire, a postcard reminder two weeks later, a second personally addressed letter and questionnaire two weeks later, and finally a second postcard reminder. Based on our collected GFB farmer list, 1,050 surveys were sent throughout the U.S. as shown in Figure 4.2. Each state is represented by at least one farmer, with a maximum of 77 farmers in New York.

Three-hundred eighty-four responses were collected for an adjusted response rate of 41%, considering bad addresses and farmers no longer in the GFB business. Respondents were asked

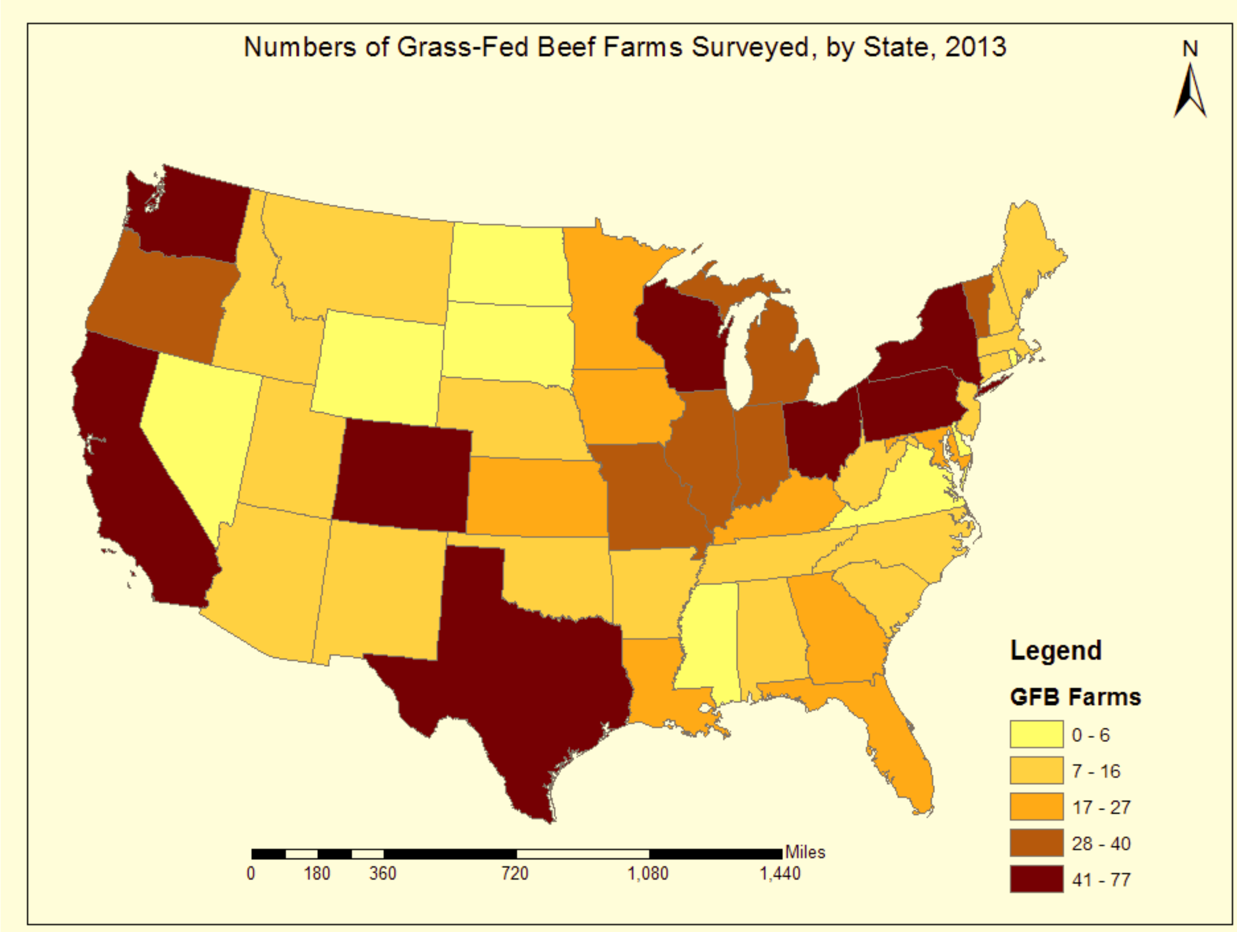

Figure 4.2. Numbers of U.S. Grass-Fed Beef Farms Surveyed, by State, 2013

if they would be willing to fill out a follow-up survey on costs and returns. Two-hundred fifty-seven farmers indicated they would be willing to participate. The responses to the first survey represented the country as shown in the Figure 4.3.

The follow-up survey collected information on farm input expenses and returns for 2012. Questions were worded in a similar manner to USDA's Agriculture Resource Management Survey questions on costs and returns. Detailed information on income and expenses was collected using this survey. To capture the income of both the whole farm and the GFB enterprise, questions eliciting information on the following were included: sales of all crops excluding hay, sales of animals and animal products other than GFB animals, hay sales, the

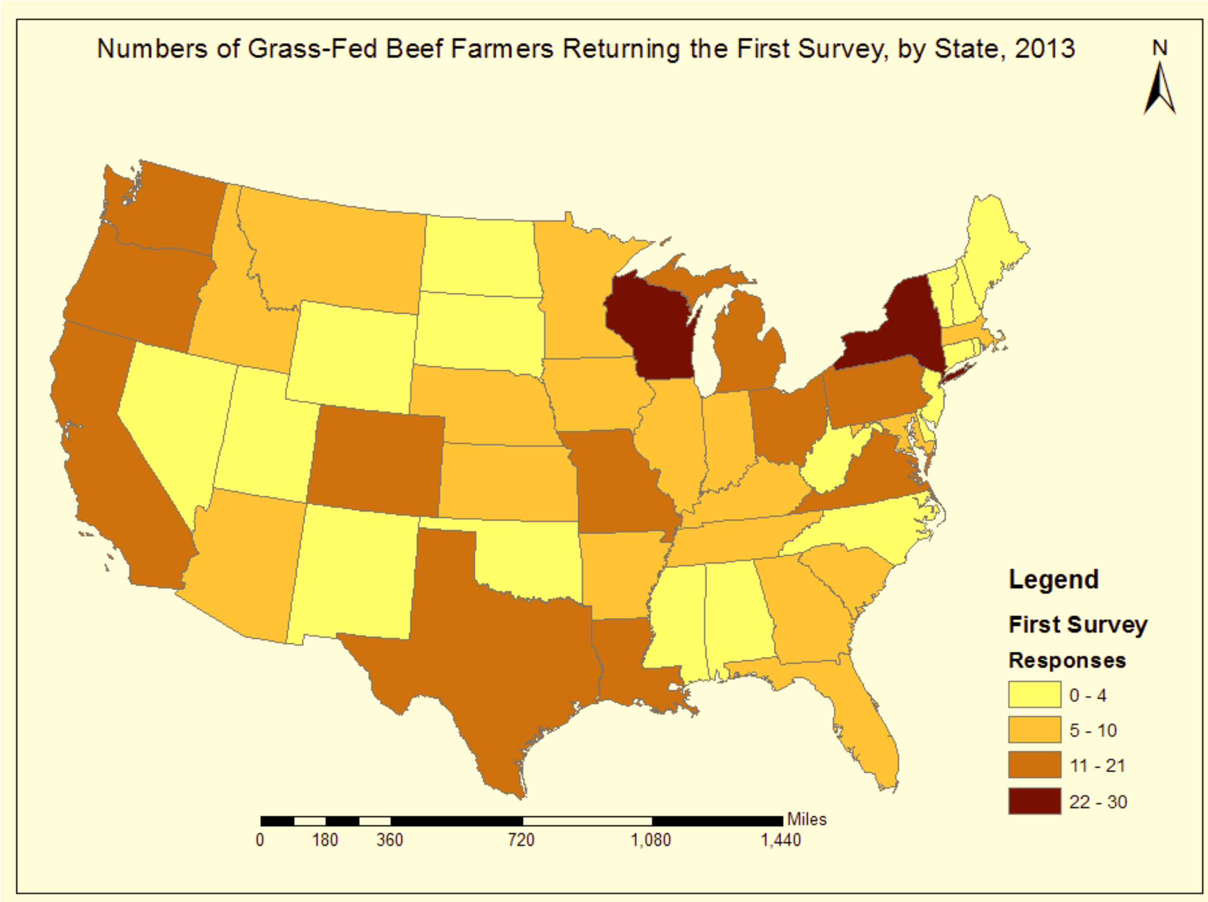


Figure 4.3. Numbers of Grass-Fed Beef Farmers Returning the First Survey, by State, 2013

percentage of hay sold that was produced from the GFB pasture, and sales of GFB meat and animals. Similarly, the following operational expenses were included: seed, fertilizers, feeder animals, purchased feed, bedding material, veterinary and medical, fuel, electricity, farm supplies, repair and maintenance expenses of machinery and equipment, hired labor, cash value of noncash payment for farm work, value of farm management services, and custom work. Fixed expenses included: insurance for the farm business, interest and fees paid on debts for the operation, taxes, rent of buildings, rental of machinery and equipment, licensing fees, and depreciation costs of machinery and equipment. The three page survey questionnaire is included in Appendix B. Of the 257 surveys sent, we received an adjusted response rate of 33%, with 85 observations on returns and expenses of U.S. GFB producers. We used 81 observations due to the incompleteness of four surveys. The distribution of the second survey responses by state is shown in Figure 4.4.

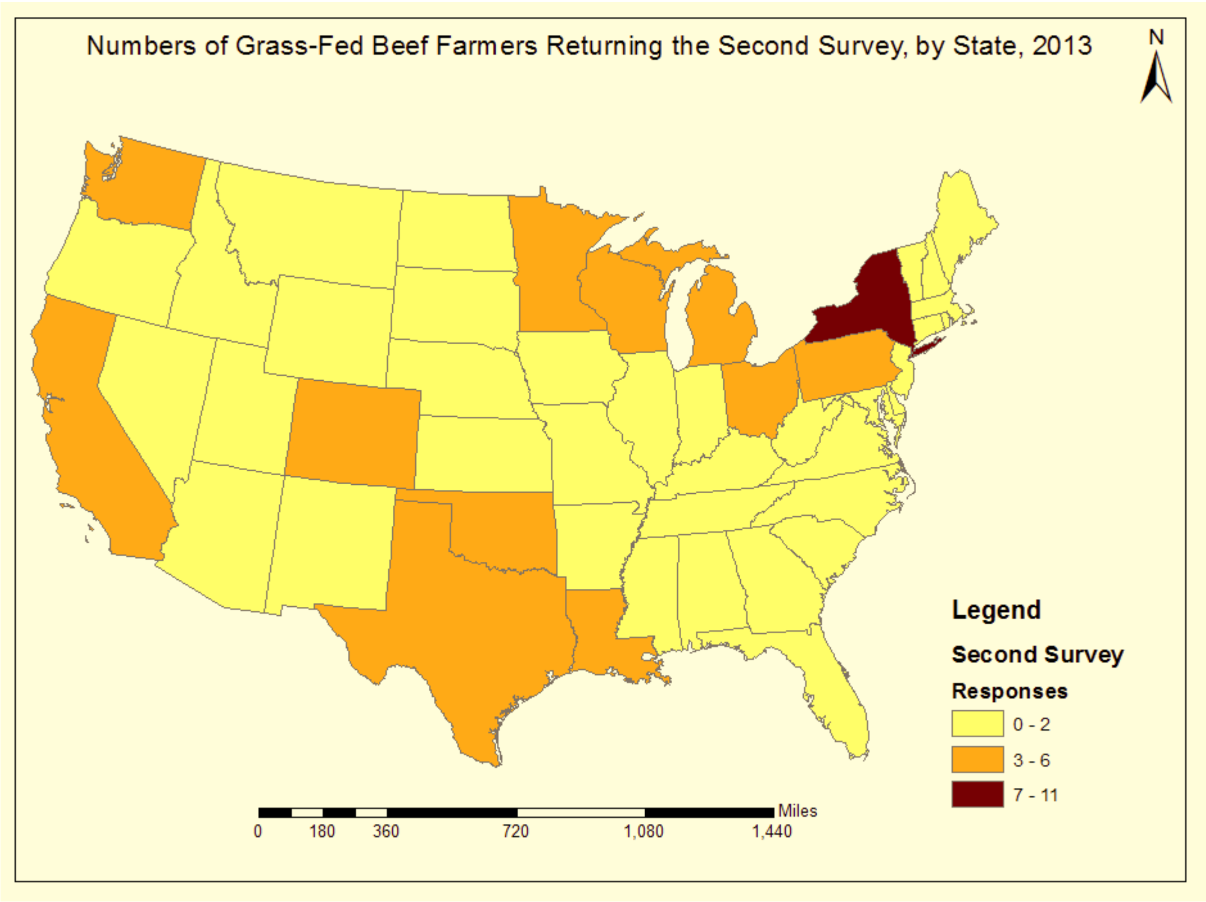


Figure 4.4. Numbers of Grass-Fed Beef Farmers Returning the Second Survey, by State, 2013

As in most survey data, there were some missing values in some survey responses. This might be due to either unintentional skipping of questions during survey completion or respondents deciding not to answer a particular question. Various imputation methods such as single imputation using mean/mode and substitutions, and multiple imputation methods are generally used for imputation (Allison, 2000). Multiple imputation is a popular method as it imputes different values which represent the reality of the farm situations. It introduces random variation and enhances the possibility of obtaining unbiased estimates of the parameters (Allison, 2000; Schafer, 1997). We used the multiple imputation method as developed by Rubin (1987) and Schafer (1997) to impute missing values. We imputed 8 values for missing depreciation expenses and 6 values for cash value expenses. These imputed values constituted a very small fraction of total expenses. The depreciation and cash values expenses were not more than 15% of the total expenses.

We use a Cobb-Douglas production function in a stochastic frontier framework to analyze the efficiency of GFB producers. The Cobb-Douglas production function is widely used to represent production functions (Samarjeeva et al., 2012; Khai and Yabe, 2011). It is flexible, relatively easy to compute and interpret, and consistent with the law of diminishing returns (Murthy, 2002). The output is revenue from the GFB enterprise and input variables include quality adjusted land value, feed costs, other variable costs, fixed costs, and labor costs, respectively. Grass-fed beef output includes GFB and GFB animals sold as well as any hay sold from the GFB enterprise. Since some of these farms did not use purchased feed and hired labor, dummy variables for feed and labor were used to represent observations where there were zero values. Battese (1997) suggested that including zero values in the explanatory variables may lead to biased estimates which can be estimated in an unbiased way using dummy variables.

Land input expenses include quality adjusted land values. The quality adjusted land cost was used in the analysis because land values are affected by soil type, soil characteristics, urban influences, and other productivity-related factors (Nehring, Ball, and Breneman, 2002). Land values of urban and rural areas differed from each other and these cannot be directly compared. Analysis without taking into account the quality adjustment would likely yield biased estimates of technical efficiency. Ball et al. (1997) and Nehring et al. (2006) used hedonic regression techniques to construct a quality adjusted land value by accounting for the effects of land characteristics on land prices. The quality adjusted land values for different states in 2012 were calculated using the estimated quality adjusted land prices by U.S. states for 2004 as developed by Nehring et al. (2006) and estimation of proportionate increases in pasture land values between 2004 and 2012. These are multiplied by the acreage of the farms and service flow to get the quality adjusted land value as per the specific farms. According to Nehring et al. (2006), the service flow of land is estimated assuming the farm's agricultural activities for 20 years based on the interest of 6%.

Feed input expenditures include the use of hay and silage during the winter season. Other variable expenditures include marketing charges, seed, fertilizers, pesticides, weaned animal expenditures, veterinary and medical, farm supplies, fuel, electricity, repair and maintenance, custom work, cash value for noncash payment for farm work, and farm management services. Fixed expenditures include insurance, interest on debt, property taxes, rental of building structures and equipment, licensing fees, and depreciation. The labor input expenses include cash wages paid to hired farm and ranch labor plus payroll taxes and benefits. It includes cash wages, incentives and bonuses, and payment to other operators and paid family members if they received a wage.

Inefficiency effects in the stochastic frontier framework are considered as farm and farmer characteristics, including herd size, education of the head of the household, percentage of farm income from the GFB enterprise, percentage of total household income that was from off-farm income, farmer experience, farmer gender, percentage contribution of beef meat sold in the total GFB income, the presence of a cow-calf enterprise, and regions of the U.S. Herd size was divided into three groups, those having >90 head as the large herd size, having >30 and ≤ 90 head as the medium herd size and those with ≤30 head as the small herd size, dummy variables were used. A positive relationship between farm size and technical efficiency is expected (Morrison-Paul et al., 2004; Somwaru and Valdes, 2004; Nehring et al., 2012; Samarajeewa et al., 2012).

Education was measured as having a Bachelor's or higher academic degree. Seventy percent of the GFB farmers held a Bachelor's or higher academic degree. We expect a positive relationship between technical efficiency and education as in Krasachat (2008). The contribution of GFB income to the total farm income was categorized into five levels in 20% intervals. We expect a positive relationship between the income contribution of the GFB enterprise and technical efficiency (Krasachat, 2008; Rakipova, Gillespie and Franke, 2003). Similarly, the percentage contribution of off-farm income to total farm income was included using five levels with 20% intervals. The literature does not show a conclusive relationship between off-farm income and farm technical efficiency (Otieno, Hubbard, and Ruto, 2012; Nehring and Fernandez-Cornejo, 2006; Tipi et al. 2009).

Farmer experience was measured as the number years the farmer had operated the GFB farm. A positive relationship is expected between years of experience and farm efficiency (Otieno, Hubbard, and Ruto, 2012; Krasachat et al., 2008). We found that 20% of the GFB farms were operated by females. Most previous studies have found negative relationships between female farm headed households and technically efficiency (Holden, Shiferaw, and Pender, 2001, Kinkingninhoun-Medagbe, et al. 2010; Peterman et al. 2011, Ogunniyi and Ajao, 2010) while some have reported positive relationships (Oladeebo and Fajuyigbe, 2007; Dadzie and Dasmani, 2010).

About 63% of the average farm's GFB income was from GFB meat sold. About 78% of the GFB farms included the cow-calf segment. A dummy variable was included to represent whether or not the farms included a cow calf operation. The percentage contribution of GFB meat sold in GFB income and cow-calf variables were included to explore their potential impacts on technical efficiency.

For the analysis, regions were divided into four different categories, the Northeast, Midwest, Southeast, and West. States in Northeast region included Connecticut, Massachusetts, New Hampshire, New York, and Pennsylvania. The Midwest included Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The Southeast included Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, South Carolina, Virginia, and West Virginia. The West included Arizona, California, Colorado, Idaho, Montana, Nebraska, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. Regional dummy variables were used for the different regions to consider their potential impacts on technical efficiency.

The descriptive statistics for the variables used in the model are presented in Table 4.1. This shows that average income from the grass-fed enterprise was $58,146, ranging from $700 to $720,000. Only about 28% of GFB farms surveyed used purchased feed for their operations. Similarly, about 11% of the farms were not using hired and /or family labor. The average quality adjusted land value (service flow) was $44,195, ranging from $398 to $636,079. Feed expense was in the range of $0 to $97,200. Average feed expense was $5,184. Other variable expenses

Table 4.1. Summary Statistics of Variables in the Model

| Variables | Units | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Grass-fed Output Value | US$ | 58,145.81 | 103,443.20 | 700.00 | 720,000.00 |
| Feed | 0-1 | 0.28 | 0.45 | 0.00 | 1.00 |
| Labor | 0-1 | 0.53 | 0.50 | 0.00 | 1.00 |
| Quality Adjusted Land Value | US$ | 44,194.59 | 99,265.53 | 398.29 | 636,078.60 |
| Feed Expenses | US$ | 5,184.30 | 11,908.46 | 1.00 | 97,200.00 |
| Other Variable Expenses | US$ | 25,898.77 | 35,723.45 | 31.67 | 227,140.00 |
| Fixed Expenses | US$ | 17,773.88 | 24,232.59 | 220.00 | 186,612.00 |
| Labor Expenses | US$ | 4,149.94 | 12,202.05 | 1.00 | 61,550.00 |
| Technical Inefficiency Variables | | | | | |
| Large Herd (>90 animals) | 0-1 | 0.30 | 0.50 | 0.00 | 1.00 |
| Medium Herd | 0-1 | 0.37 | 0.49 | 0.00 | 1.00 |
| (>30 and $\leq$ 90 animals) | | | | | |
| College Education | 0-1 | 0.70 | 0.46 | 0.00 | 1.00 |
| Percentage of Grass-Fed Income in Total Farm Income | Intervals of 20% Coded 0-5 | 2.94 | 1.73 | 1.00 | 5.00 |
| Percentage of Off-farm Income in Total Farm Income | Intervals of 20% Coded 0-5 | 3.43 | 1.61 | 1.00 | 5.00 |
| Experience | Years | 11.10 | 7.96 | 3.00 | 41.00 |
| Female | 0-1 | 0.20 | 0.40 | 0.00 | 1.00 |
| Percent Contribution of Beef Meat Sold in GFB Income | Percent | 63.09 | 40.47 | 0.00 | 100.00 |
| Having Cow-calf Operation | 0-1 | 0.78 | 0.42 | 0.00 | 1.00 |
| Northeast | 0-1 | 0.21 | 0.41 | 0.00 | 1.00 |
| Midwest | 0-1 | 0.23 | 0.43 | 0.00 | 1.00 |
| Southeast | 0-1 | 0.22 | 0.42 | 0.00 | 1.00 |

ranged from \$32 to \$227,140 with an average of \$25,899. Average fixed expenses were \$17,774 ranging from \$220 to \$186,612. Labor expenses ranged from \$0 to \$61,550 and the average labor expense among those farms using labor was \$4,150. We excluded unpaid family labor and operator labor from our computation.

**4.3. Econometric Methods**

4.3.1 Estimation of Technical Efficiency

Technical efficiency measures how efficiently a given set of inputs are used to produce output. There is inefficiency if there exists the opportunity to reduce the use of input to produce the same level of output. It can be defined as

$$\mathrm{TE} = \sum_{r=1}^{s} \mathrm{Yrk} / \sum_{i=1}^{m} \mathrm{Xik}$$

where Yrk is the outputs r produced by firm k and Xik is inputs i used by firm k to produce outputs. Parametric stochastic production frontier and non-parametric DEA methods are commonly used to measure technical efficiency (Morrison-Paul et al. 2004; Wadud and White, 2000). The parametric stochastic frontier method is used in this study. We use parametric methods because they are less influenced by extreme values, unlike DEA (Wadud and White, 2000). Stochastic production frontier methods, originally proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) are widely used in efficiency models. The production function can be defined as:

$$y = f(x)\, \exp^{(v-u)}, \tag{1}$$

where x is the vector of inputs and y is the output. The increasing concave function is represented by $f(x)$, v represents the independently and identically distributed random error component which has a normal distribution of 0 mean and $\sigma^2_v$, and u represents a one-sided non-negative error term, having a half normal distribution.

A two-stage procedure for estimating technical efficiency has been used in much of the previous literature (Wadud and White, 2000; Iraizoz, Rapun, and Zabaleta, 2003), which consists of estimation of the stochastic frontier, prediction of technical efficiency scores in the first stage, and determination of the impacts of explanatory variables on the technical efficiency scores in the second stage. Other studies have suggested that the two-step procedure is inconsistent and results in biased estimates, which could be overcome by using a one-step procedure (Wang and Schmidt, 2002; Battese and Coelli, 1995). In this single step procedure, the stochastic frontier function and technical inefficiency effects are estimated together using maximum likelihood procedures. In this case, equation (1) can be modified to address the heterogeneity in the inefficiency (u) as:

$$y = f(x;\beta) + v - u(r, \delta'), \qquad u(r, \delta') \geq 0 \tag{2}$$

$$\sigma^2_u = \exp(\delta' r), \tag{3}$$

where $\sigma^2_u$ is the variance of the inefficiency term and r represents explanatory variables of inefficiency as farmer demographics and farm characteristics. Technical efficiency (TE) of the farm is estimated as:

$$TE = \exp^{(-u)}, \; 0 < TE < 1 \tag{4}$$

4.3.2. Comparison of GFB Production Costs and Returns by Operation Size

Farm size is generally one of the major factors impacting farm production costs (Morrison-Paul et al., 2004). In this study, the returns and expenses are evaluated by operation size. The GFB operations were divided into three groups based on number of head raised to slaughter weight and farm acreage devoted to the GFB enterprise. Comparisons among different operation sizes were made using t- test procedures. Each of the variable expenses, total variable expenses, each of the fixed expenses, and total fixed expenses were compared among the various operation sizes. Revenue, total expenses, return over variable expenses, and return over the total expenses were also compared. For most of the expenses, farmers reported both the expense for whole farm and for the GFB enterprise as per the survey questionnaire. We use the reported enterprise revenue and expenses in this analysis. For those expenses (repair expense, insurance expense, property tax expense, licensing fees, depreciation expense, custom work expense, cash value expense for noncash payment for farm labor, farm management services) where they were not asked to specifically allocate expense to the GFB enterprise, the GFB enterprise expense was calculated by dividing the GFB revenue by total farm revenue and multiplying the quotient by the reported values.

## 4.4. Results

### 4.4.1 Technical efficiency

The results of the estimation of the Cobb-Douglas production function using the stochastic frontier model are presented in Table 4.2. We assumed a half normal distribution of the technical efficiency parameter. As expected, feed costs, other variable costs, fixed costs and labor costs had positive and significant effects on grass-fed beef production. Unlike some other studies (Qushim, Gillespie, and McMillin, 2014), land was not significant in this study.

Since this is a double-log Cobb-Douglas model, the coefficients can be interpreted as elasticities. Feed is positive and significant at the 1% level, meaning that greater purchased feed

Table 4.2. Stochastic Production Frontier Results, U.S. GFB Production

| Variables | Coefficients | Standard Error |
|---|---|---|
| Stochastic Frontier Model | | |
| Feed | 2.392*** | 0.629 |
| Labor | 1.580*** | 0.471 |
| Quality Adjusted Land Value | 0.013 | 0.045 |
| Feed Expenses | 0.261*** | 0.070 |
| Other Variable Expenses | 0.347*** | 0.069 |
| Fixed Expenses | 0.295*** | 0.068 |
| Labor Expenses | 0.254*** | 0.059 |
| Constant | 0.458 | 0.605 |
| lnsig2v | -1.422*** | 0.266 |
| Inefficiency Model | | |
| Large Herd (>90 animals) | 1.069* | 0.612 |
| Medium Herd (>30 and <= 90 animals) | 1.731** | 0.720 |
| College Education | -0.617 | 0.647 |
| Percentage of Grass-Fed Income in Total Farm Income | -0.699*** | 0.230 |
| Percentage of Off-farm Income in Total Farm Income | 0.334** | 0.168 |
| Experience | -0.126 | 0.077 |
| Female | 0.646 | 0.939 |
| Percent Contribution of Beef Meat Sold in GFB Income | -0.026** | 0.011 |
| Having Cow-Calf Operation | 27.425* | 3.034 |
| Northeast | 1.344* | 0.748 |
| Midwest | -2.081** | 0.873 |
| Southeast | -0.367 | 1.067 |
| Constant | -26.014*** | 4.066 |

Notes: *, **, and *** indicate the significance at 10, 5 and 1% level of significance, respectively.

yielded greater output. Similarly, labor is positive and significant at the 1% level. It means that greater hired labor yielded higher output. The coefficient for feed expense is 0.26, which is significant at the 1% level. This means that if feed expense increased by 10% holding all else constant, output would be increased by 2.6%. The largest effect on output is from other variable costs, with a coefficient of 0.35 and significance at the 1% level. If variable costs were increased by 10% holding all else constant, output would be increased by 3.5%. The coefficient of fixed expenses is 0.30 and is significant at the 1% level, meaning that if the fixed expenses increased by 10% holding all else constant, a 3.0% increase in output would result. Finally, if labor costs were increased by 10% holding all else constant, the output would increase by 2.5%.  The sigma squared value was significant at the 1% level, meaning that the stochastic frontier model was significant.

In the Cobb-Douglas model, the coefficients are elasticities and the sum of these coefficients is interpreted as the return to scale. The sum of the input coefficients was 1.17, meaning that GFB production is operating with increasing returns to scale. This means that increasing all inputs by 10%, output will be increased >10%, (11.7%). When farms are operating with increasing returns to scale, they maximize profit by increasing input usage. This indicates that this industry is in the developmental phase. Producers can expand their operations until they achieve constant returns to scale, at which point increasing all inputs by 10% will result in a 10% increase in output.

The lower portion of Table 4.2 presents the technical inefficiency effects. Unlike some previous studies (Morrison-Paul et al., 2004; Somwaru and Valdes, 2004; Nehring et al. 2012; Samarajeewa et al., 2012), herd size was negatively related to technical efficiency in this study.

Both medium-sized herds and large herds were less efficient than smaller herds. This might be due to greater attention paid to individual animals on smaller farms and the fact that we do not include operators and unpaid family labor. As per our expectation, specialization in GFB enterprise has a significant negative impact on technical inefficiency. In cases where the contribution of GFB income to the total farm income was greater, the farm was more technically efficient. Similar impacts of farm specialization on farm efficiency have been found in previous studies (Rakipova, Gillepie, and Franke, 2003; Krashachat, 2010).

If the farm's percentage share of off-farm income to total household income was greater, then the farm was less efficient. This finding contradicts the results by Nehring et al. (2005) and Otieno, Hubbard, and Ruto (2012); however, it supports the finding by Tipi et al. (2009). The possible explanation would be devotion of greater attention to off-farm enterprise. A higher percentage share of GFB meat sold in total GFB income was positively related with technically efficiency. Farms involved in the cow-calf segment were less efficient than farms that were not. The cow-calf segment may divert attention from the GFB segment, negatively impacting technical efficiency. Farms located in the Midwest region were more efficient relative to farms in the West while Northeast region farms were less efficient to farms in the West.

Table 4.3 presents the mean technical efficiency score among GFB farms in the U.S. The average technical efficiency of the GFB farms was 0.76. This suggests that on average, with better management, GFB producers can produce at their present levels by decreasing inputs by 24%. The distribution of technical efficiency scores among GFB producers is presented in Table 4.4. This shows that more than 70% of the farms were producing at higher than 70% efficiency.

Table 4.3. Technical Efficiency

| Summary Statistics | Technical Efficiency |
|---|---|
| Mean | 0.76 |
| Standard Deviation | 0.25 |

Table 4.4. Distribution of Technical Efficiency

| Range of TE | Frequency | Percentage of Farms |
|---|---|---|
| 0.00<TE≤ 0.10 | 1 | 1.23 |
| 0.10<TE≤ 0.20 | 3 | 3.70 |
| 0.20<TE≤ 0.30 | 2 | 2.47 |
| 0.30<TE≤ 0.40 | 4 | 4.94 |
| 0.40<TE≤ 0.50 | 2 | 2.47 |
| 0.50<TE≤ 0.60 | 5 | 6.17 |
| 0.60<TE≤ 0.70 | 7 | 8.64 |
| 0.70<TE≤ 0.80 | 12 | 14.81 |
| 0.80<TE≤ 0.90 | 14 | 17.28 |
| 0.90<TE≤ 1.00 | 31 | 38.27 |

### 4.4.2. Comparison of Costs and Returns of Grass-Fed Beef Farms in the U.S. by Size

Grass-fed beef farms were divided into approximately three equal groups based on numbers of GFB cattle raised to harvest weight. Since there were 5 farms that raised no animals for harvest in 2012, those observations were dropped for this comparison. With those observations, it was impossible to compute the revenue and expenses on a per-animal-produced basis. Farms producing ≤9 harvest cattle were considered small farms, farms producing 9 to 24 harvest cattle were considered medium-sized farms, and farms producing >24 harvest cattle were considered large farms. Thus, 25 farms were categorized as small, 26 farms as medium-sized, and 25 farms as large-sized. Results of the comparison of returns and expenses among the different sized farms are presented in Table 4.5.

Revenue per animal was higher on medium-sized farms than on large farms. Large farms had lower revenue, were more likely to be located in the West, and were likely to include the cow-calf segment (Table 4.6).

Feed expense per animal, which included purchased feed and/or forage, was lower on large farms than on medium-sized and small farms. Chemical expenses, which included pest control and its custom application, were lower for large farms than medium-sized farms. Weanling calf expense was higher for large farms than medium-sized and small farms. Bedding expense per animal was higher on small farms than on medium-sized and large farms. Veterinary and medical expense per animal differed by operation size with the highest for small farms and lowest for large farms. Fuel and electricity expenses per animal were lower for large farms than for medium-sized and small farms. Repair and maintenance expenses per animal were lower for large farms than small and medium-sized farms.

Cash value expense, which includes all noncash payment for farm work, was lower for large farms than for medium-sized and small farms. Farm management services expenses were lower on large farms than on small and medium-sized farms. Total variable expenses per animal for large farms than for medium-sized and small farms. Return over the total variable expenses per animal was negative for small farms while it was positive for medium-sized and large farms. Large farms had higher return over total variable expenses than medium-sized and small farms.

Insurance expense per animal was lower on large farms than on small and medium-sized farms. Interest expenses per animal were lower on large farms than on small farms. Rental expense

Table 4.5. Grass-Fed Beef Production Return and Expense per Animal Produced

| Return and Expenses | Small Farms ($\leq$9) | Medium Farms (>9 & $\leq$ 24) | Large Farms (>24) |
|---|---|---|---|
| Revenue | 2380.20 | 2196.64$^{c}$ | 1778.79$^{b}$ |
| Variable Expenses | | | |
| Feed | 517.86$^{c}$ | 355.41$^{c}$ | 86.20$^{ab}$ |
| Labor | 57.70 | 387.74 | 134.00 |
| Fertilizer | 82.02 | 41.56 | 34.83 |
| Marketing | 93.43 | 67.27 | 62.57 |
| Seed | 80.85 | 11.69 | 18.88 |
| Chemicals | 5.46 | 7.72$^{c}$ | 2.50$^{b}$ |
| Weaning Calf | 102.63$^{c}$ | 151. 87$^{c}$ | 298.15$^{ab}$ |
| Bedding Materials | 15.2$^{bc}$ | 2.17$^{a}$ | 3.22$^{a}$ |
| Veterinary and Medical | 148.87$^{bc}$ | 55.13$^{ca}$ | 14.84$^{ab}$ |
| Fuel | 199.93$^{c}$ | 175.15$^{c}$ | 75.89$^{ba}$ |
| Electricity | 91.32$^{c}$ | 102.28$^{c}$ | 43.05$^{ab}$ |
| Supplies | 101.89 | 100.18 | 72.30 |
| Repair | 295.77$^{c}$ | 233.67$^{c}$ | 75.74$^{ab}$ |
| Maintenance | 255.66$^{c}$ | 91.76$^{c}$ | 42.72$^{ab}$ |
| Cash Value | 174.55$^{c}$ | 139.71$^{c}$ | 38.26$^{ab}$ |
| Farm Management Services | 67.63$^{c}$ | 63.92$^{c}$ | 9.29$^{ba}$ |
| Custom work | 135.18 | 66.28 | 51.51 |
| Total Variable Expenses | 2426.22$^{c}$ | 2053.50$^{c}$ | 1063.96$^{ab}$ |
| Return over Variable Expenses | -46.02$^{c}$ | 143.14$^{c}$ | 714.83$^{ab}$ |
| Fixed Expenses | | | |
| Insurance | 152.18$^{c}$ | 200.61$^{c}$ | 43.11$^{ab}$ |
| Interest | 198.03$^{c}$ | 226.05 | 50.51$^{a}$ |
| Rent for Machinery | 0.00$^{bc}$ | 10.90$^{ca}$ | 1.56$^{ab}$ |
| Rent for Land | 29.73$^{b}$ | 110.41$^{a}$ | 95.19 |
| Tax | 449.67$^{c}$ | 197.68$^{c}$ | 48.82$^{ab}$ |
| Licensing Fees | 20.71 | 26.99 | 13.08 |
| Depreciation | 889.06$^{c}$ | 710.69$^{c}$ | 203.83$^{ab}$ |
| Total Fixed Expenses | 1739.38$^{c}$ | 1483.33$^{c}$ | 456.11$^{ab}$ |
| Total Specified Expenses | 4165.60$^{c}$ | 3536.83$^{c}$ | 1520.07$^{ab}$ |
| Return over Total Expenses | -1785.40$^{c}$ | -1340.19$^{c}$ | 258.72$^{ab}$ |

Note: Superscript a, b, and c indicate significant differences at $p<0.10$ in means across rows with a = small farms with less than or equal to 9 harvest animals, b = medium-sized farms with 9 to 24 harvest animals, and c = large farms with more than 24 harvest animals.

Table 4.6. Distribution of Different Sized Farms Based on Number of Animals, Region, and Whether the Farm Included the Cow Calf Segment

| Region/ Cow Calf | Small Farms (≤ 9 animals) | Medium Farms (>9 and & ≤ 24 animals) | Large Farms (24 animals) | Total |
|---|---|---|---|---|
| West | 5 | 11 | 11 | 27 |
| Midwest | 8 | 5 | 6 | 19 |
| Northeast | 5 | 4 | 4 | 13 |
| Southeast | 7 | 6 | 4 | 17 |
| Total | 25 | 26 | 25 | 76 |
| Cow Calf | 20 | 18 | 20 | 58 |
| No Cow Calf | 5 | 8 | 5 | 18 |

per animal for machinery and equipment differed among various size operations, with the highest for medium-sized farms and the lowest for small farms. Rental expense per animal for leasing land for the farm operation was higher on medium-sized farms than small farms. Tax expense per animal was lower for large farms than for medium-sized and small farms. Depreciation expense per animal was lower on large farms than on medium-sized and small farms. Total fixed expenses per animal were lower on large farms than on small and medium-sized farms.

Total specified expenses per animal, which include total variable expenses and total fixed expenses, were lower for large farms than for medium-sized and small farms. Return over total specified expenses per animal was higher for the large farms than for medium-sized and small farms.

Operations were divided into three groups based on farm acreage devoted to the GFB enterprise. Large farms included >250 acres, medium-sized farms included >66 acres and ≤ 250 acres, and small farms included ≤ 66 acres. Twenty-nine farms were categorized as small, 28 farms as medium-sized, and 24 farms as large. Comparisons of returns and expenses on per acre bases for the different operation sizes are presented in Table 4.7.

Table 4.7. Grass-Fed Beef Production Return and Expense per Acre

| Return and Expenses | Small Farms ($\leq$66) | Medium Farms (>66 & $\leq$ 250) | Large Farms (>250) |
|---|---|---|---|
| Revenue | 744.14$^{bc}$ | 313.16$^{ac}$ | 114.30$^{ab}$ |
| Variable Expenses | | | |
| Feed | 108.16$^{bc}$ | 22.96$^{ac}$ | 12.60$^{ab}$ |
| Labor | 18.43 | 39.46 | 13.00 |
| Fertilizer | 14.63$^{bc}$ | 5.70$^{a}$ | 2.80$^{a}$ |
| Marketing | 14.90$^{c}$ | 13.26 | 3.03$^{a}$ |
| Seed | 5.23$^{c}$ | 2.86 | 1.81$^{a}$ |
| Chemicals | 2.53$^{bc}$ | 0.80$^{ac}$ | 0.20$^{ab}$ |
| Weanling Calf | 91.29$^{c}$ | 64.98$^{c}$ | 18.14$^{ab}$ |
| Bedding Materials | 4.58$^{bc}$ | 0.68$^{a}$ | 0.11$^{a}$ |
| Veterinary and Medical | 11.06$^{bc}$ | 4.85$^{ac}$ | 2.02$^{ab}$ |
| Fuel | 20.34$^{c}$ | 13.09 | 8.91$^{a}$ |
| Electricity | 11.71$^{c}$ | 11.08$^{c}$ | 3.94$^{ab}$ |
| Supplies | 14.04$^{c}$ | 9.15 | 6.43$^{a}$ |
| Repair | 27.51$^{c}$ | 16.35$^{c}$ | 9.33$^{ab}$ |
| Maintenance | 14.92$^{c}$ | 12.04 | 5.10$^{a}$ |
| Cash Value | 29.58$^{bc}$ | 8.80$^{a}$ | 3.98$^{a}$ |
| Farm Management Services | 11.07 | 2.24 | 1.63 |
| Custom Work | 18.29$^{bc}$ | 5.33$^{a}$ | 6.97$^{a}$ |
| Total Variable Expenses | 418.39$^{bc}$ | 233.63$^{ac}$ | 100.00$^{ab}$ |
| Return over Variable Expenses | 325.75$^{c}$ | 79.52$^{c}$ | 14.31$^{ab}$ |
| Fixed Expenses | | | |
| Insurance | 20.63$^{bc}$ | 9.59$^{ac}$ | 5.37$^{ba}$ |
| Interest | 7.36 | 12.61 | 9.71 |
| Rent for Machinery | 0.88$^{b}$ | 0.00$^{a}$ | 0.72 |
| Rent for Land | 22.20$^{c}$ | 11.82$^{c}$ | 4.61$^{ba}$ |
| Tax | 51.17$^{bc}$ | 11.98$^{a}$ | 7.30$^{a}$ |
| Licensing Fees | 1.84 | 1.03 | 2.09 |
| Depreciation | 53.69 | 54.70$^{c}$ | 23.69$^{b}$ |
| Total Fixed Expenses | 157.78$^{bc}$ | 101.73$^{ac}$ | 53.48$^{ab}$ |
| Total Specified Expenses | 576.18$^{bc}$ | 335.36$^{ac}$ | 153.47$^{ab}$ |
| Return over Specified Expenses | 167.97 | -22.20 | -39.17 |

Note: Superscript a, b, and c indicate significant differences at $P < 0.10$ in means across rows with a = small farms, b = medium-sized farms, and c = large farms.

Revenue per acre differed among various operation sizes with the highest on small farms and the lowest on large farms. The lowest per acre revenue for large farms was due primarily to lower stocking rates on Western U.S. farms. Among the large farms, more than 60% were in the West where the average farm devoted >1,000 acres to the GFB enterprise. In addition, more than 90% of the large farms were involved in the cow-calf segment (Table 4.8).

Table 4.8. Distribution of Different Sized Farms Based on Acreage, Region, and Whether the Farm Included the Cow Calf Segment

| Region/ Cow calf | Small Farms (≤ 66 acres) | Medium Farms (>66 and & ≤ 250 acres) | Large Farms (>250 acres) | Total |
|---|---|---|---|---|
| West | 4 | 9 | 14 | 27 |
| Midwest | 10 | 6 | 3 | 19 |
| Northeast | 8 | 7 | 2 | 17 |
| Southeast | 7 | 6 | 5 | 18 |
| Total | 29 | 28 | 24 | 81 |
| Cow calf | 17 | 23 | 23 | 63 |
| No Cow calf | 12 | 5 | 1 | 18 |

Feed expense per acre differed among various operation sizes with the highest for small farms and the lowest for large farms. Fertilizer expense per acre was higher on small farms than on medium and large farms. Marketing expense per acre was lower on large farms than on small farms. Seed expense per acre was higher on small farms than on large farms. Chemical expense per acre differed among the operation sizes with the highest on small farms and the lowest on large farms. Weanling calf expense per acre was lower on large farms than on medium-sized and small farms. This may be due to lower stocking rates for large farms. Bedding expense per acre was higher on small farms than on medium-sized and large farms. Veterinary and medical expense per acre differed by farm size with the highest on small farms and the lowest on large farms. Fuel expense per acre was higher on small farms than on large farms. Electricity expense per acre was lower on large farms than on medium-sized and small farms. Supply expense per acre was higher on small farms than on large farms.

Repair expense per acre was lower on large farms than on medium and small farms. Maintenance expense per acre was higher on small farms than on large farms. The cash value of items provided as noncash payment for labor per acre was higher on small farms than on medium-sized and large farms. Custom work expense per acre was higher for small farms than for medium-sized and large farms. Total variable expenses per acre differed among various farm sizes with the highest on small farms and the lowest on large farms. Return over total variable expenses per acre was lower for large farms than for medium-sized and small farms.

Insurance expense per acre differed by farm size with the highest on small farms and the lowest on large farms. Rental expense for machinery and equipment per acre was higher on small farms than on medium-sized farms. Rental expense per acre for leasing land for the farm operation was lower on large farms than on medium-sized and small farms. Tax expense per acre was higher on small farms than on medium-sized and large farms. Depreciation expense per acre was lower on large farms than on medium-sized farms. Total fixed expenses per acre differed with operation size with the lowest on large farms and the highest on small farms.

Total specified expenses per acre differed by size with the lowest on large farms and the highest on small farms. On both per animal produced and per acre bases, results show size economies for GFB production; i.e. the larger the size of operation, the lower are the average costs.

Neibergs and Nelson (2010) developed a budget for a grass finished operation and found that the average per-head return over total specified costs was $523. These results cannot be directly compared with our budgets since our budgets were developed based on survey data collected in 2012. Schwab et al. (2012) estimated the production costs and breakeven market prices for GFB for 2008 and 2009. They estimated that total financial costs and economic costs per hundred weight of market animal produced were $215 and $252, respectively. Similarly, Acevedo, Lawrence, and Smith (2006) estimated that total specified costs per animal in a natural grass-fed system were $1,380, including variable costs of $1,357 which are comparable with large sized farms per animal in this study. The estimation of budgets on those studies was based on several assumptions and expectations about prices of various inputs and outputs, depreciation, interest rates and other assumptions. Our budgets are developed solely based on survey responses conducted for 2012.

**4.5. Conclusions**

GFB production has been experiencing increased attention in research and development in recent years. About one-third of U.S. beef consumers have indicated their willingness to pay premium prices for GFB (Umberger et al. 2002; Cox et al. 2005). This study applied a stochastic production frontier approach using a Cobb-Douglas production function to analyze the technical efficiency of GFB production in the U.S. The present study adds to the literature as the first analysis of technical efficiency (that we are aware of) of GFB farms in the U.S. Grass-fed beef cost and returns survey data from 2012 were analyzed to measure the technical efficiency of GFB farms. We found the inputs labor, feed, other variable expenses, and fixed expenses to have the expected positive impacts on productivity. Results show that there is increasing returns to scale among the GFB farms. Comparison of costs among the various operation sizes of GFB farms confirms that an increase in farm size results in reduced expenses per animal and per acre for the farm operation. The farms can maximize profit by increasing their scale of production.

The average technical efficiency was 0.76. Therefore, there is great opportunity to improve technical efficiency by decreasing the inputs for the same levels of output.

Technical efficiency is affected by the contribution of GFB income and off-farm income to total farm income. The contribution of GFB income to the total farm has a positive impact on technical efficiency while off-farm income has a negative impact. Farms involved in the cow-calf segment were less technically efficient than those that were not. Farms having small herd sizes were more technically efficient than medium and large herd size. This could be due to small farms pay more attention on their farms and efficiently utilize the available inputs and resources. Despite this, returns to scale and cost measures indicate a cost advantage to increasing farm size. The higher the percentage contribution of GFB meat sold to GFB income, the greater the efficiency. Farms in the Midwest were more technically efficient than those in the West while farms in the Northeast were less efficient. Specialization in GFB production would be another contributor to achieve greater technical efficiency. This can be due to the devotion of greater farm effort to the GFB enterprise.

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# CHAPTER 5: SUMMARY AND CONCLUSIONS

A wide range of pasture systems has been used for U.S. GFB production, with considerable variation in profitability and sustainability. Although the share of GFB in the total beef production in the U.S. is very low, there is a growing interest in GFB production due to human health, environmental, animal welfare, and sustainability issues. Previous research suggests about 20-30% of U.S. beef consumers are willing to pay premium prices for GFB beef; there appears to be increasing demand for GFB production in the U.S. There are few studies that focus on the economic analysis of various GFB pastures systems. This study address these issues.

An experiment was conducted at the LSU AgCenter Iberia Research Station in Jeanerette, LA, from 2009-2014 to compare three GFB pasture systems. System 1 consists of bermudagrass in the summer and ryegrass in the winter. System 2 consists of bermudagrass in the summer and ryegrass, rye, clover mix (white, red, and berseem), and dallisgrass in the winter. System 3 consists of bermudagrass, sorghum sudan hybrid, and soybean in the summer and ryegrass, rye, clover mix (white, red, and berseem), and dallisgrass in the winter. Each treatment was replicated three times. Each year in May, 54 fall-born calves were weaned and grouped into the groups of 6 and randomly placed into one of the pastures (treatment*replication). Steers were kept in the same system until harvest. For the first three years, inputs and machinery used, outputs produced, and greenhouse gas emissions among the systems were recorded and analyzed for profitability and sustainability. Five years of data on inputs, machinery, labor involvement, and outputs produced were recorded and analyzed for labor use and profitability. A cost and returns follow-up mail survey to an earlier more extensive survey was conducted in Fall 2013, with GFB producers. Of the 1,050 first round surveys sent out to GFB producers, an adjusted return rate of 41% was received with 384 usable survey returns. Of these 384 respondents, 250 indicated their willingness to participate in a follow-up cost and returns survey. Of the 250 surveys sent out, 81 usable responses were received. These survey responses were used to analyze the technical efficiency of GFB production in the U.S.

The first chapter provides information about GFB production in the U.S. and its share of total beef production. The impact of consumer interest and research and development attention for GFB is highlighted in this chapter. The second chapter analyzes the profitability and sustainability of three pasture systems based on the three years of experimental data. We determined the most profitable and most sustainable pasture systems along with the trade-offs among the systems. We found that the least complex system, System 1 was the most profitable and the most complex system, System 3 was the least profitable among the three systems of production. System 2 produced equivalent economic profit with System 1 and more profit than System 3. However, on the basis of greenhouse gas emissions, System 3 was the best since it produced the lowest carbon-dioxide equivalent emissions. System 1 produced the most carbon-dioxide equivalent emissions.

Simulations and dominance techniques were used to verify the result of the cost and return analysis. Stochastic Dominance with Respect to Function (SERF) analysis showed that Systems 1 and 2 dominated System 3. However, based on the decision maker's risk preference, they might switch from System 1 to 2. If the decision maker were more risk averse, then he or she would choose System 2 over System 1. Moreover, the following trade-offs were found between economic profitability and environmental sustainability as measured in the kilograms of

$CO_2$ equivalent emissions. If reduced $CO_2$ equivalent emissions were valued at $0.014/kg, then Systems 1 and 3 would be economically equivalent. Similarly, if reduced $CO_2$ equivalent emissions were valued at $0.040/kg, then Systems 2 and 3 would be economically equivalent. System 2 may dominate System 1 since it produced statistically equivalent profit and had numerically lower $CO_2$ equivalent emissions than System 1. Torrico et al. (2014) found higher sensory scores for meat produced under System 3, which has further implications for system choice.

The third chapter analyzes labor use and profitability. The results showed that Systems 1 and 2 were more profitable than System 3 whether or not labor was included in the calculation of expenses. The labor per animal per year was in the range of $127 to $165 among the systems. Thus, the residual incomes per animal per year after including the labor inputs were $381, $331, and $178, respectively for Systems 1, 2, and 3. Without including the labor inputs, they were $546, $458, and $305, respectively for Systems 1, 2, and 3. Results of simulation and dominance analysis also confirmed that Systems 1 and 2 were more profitable than System 3. Without including labor, System 1 also dominated System 2 throughout. Including the labor inputs, the decision maker might choose between Systems 1 and 2 based on their risk preference.

The fourth chapter analyzes the technical efficiency of GFB production based on cost and returns survey data. We found that average technical efficiency of U.S. GFB farms was 0.76, which means that the average farm was running at the 76% level of technical efficiency. The distribution of technical efficiency ranged from less than 10% to more than 90%. More than 70% of farms were running above the 70% efficiency level. Therefore, there is much room for the improvement of technical efficiency. Technical efficiency was affected by the contribution of

GFB income to the total farm income, the contribution of off-farm income to the total farm income, the contribution GFB meat sold to the GFB income and owning cow-calf segment. The contribution of GFB income to the total farm income and the contribution GFB meat sold to the GFB income were positively related to technical efficiency. Farms involved in the cow-calf segment were less technically efficient than those that were not. Similarly, if the percentage contribution of off-farm income to the total farm income is higher, then the farms would be less technically efficient. This could be due to focusing on off farm enterprises. Increasing return to scale was found, indicating that expansions of the inputs by 10%, increased output by 11.7%. Costs and returns estimates further support the expansion to large sized GFB enterprises, with average costs declining with size.

These experiments are replicable for other regions in the U.S. to determine the most profitable and sustainable pasture systems for GFB production in the respective regions. Some of the experimental results might need further testing in farmers' fields for their wider scale application. Further study including greenhouse gas impacts over longer periods of time are recommended particularly to determine the impact of carbon sequestration in the soil. Similarly, economic trade-offs including measures of beef quality would provide useful information.

This study enriches the literature on GFB production in the U.S. by addressing the economics of pasture systems and analyzing farm technical efficiency and production costs. Since farm specialization is positively related with technical efficiency of GFB production, extension program should focus on educational training on various technical issues including the important of specialization to farmers. These results are useful for the planning of GFB programs at the individual, farm, state and national level.

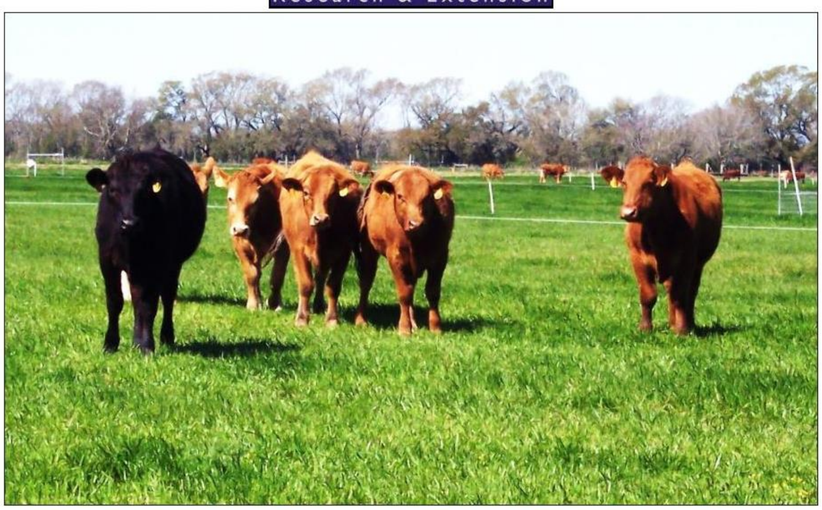
# APPENDICES

## Appendix A. The First Survey

# U.S. Grass-fed Beef Production

# Survey

LSU AgCenter Research & Extension



**Throughout this survey, you will be asked questions about your grass-fed beef farm and how you make production decisions. Please circle the answers that best reflect your situation. All information will be held as *strictly confidential*. This is a condition of the grant funding for this project. Thank you!**

## Section I. Farm Operation

**Definition of grass-fed beef** – *Grass-fed/finished beef refers to beef from cattle whose lifetime diet consists only of grass and other forage (no grains are fed), with the exception of milk consumed prior to weaning. Some would call thi forage-fed/finished beef.*

1. Did this farm raise any grass-fed beef cattle at any time during 2012? (Please circle one)
   (a) Yes →**[Please continue with 2]**
   (b) No →**[Please stop and return the questionnaire in the envelope provided. Thank you.]**

2. How many years have you been operating your grass-fed beef enterprise? ________ (years)

3. The following production segments may be present on a grass-fed beef farm:
   **Cow calf segment** - *Producing weaned calves*
   **Seedstock segment** - *Producing livestock with documented pedigrees for eventual sale as breeding stock*
   **Stocker segment** - *Keeping weaned/lightweight feeder calves on forage up to a pre-finishing weight phase*
   **Finishing segment** - *The forage feeding phase to produce cattle that are ready for harvest*

   Please select the production system(s) you have on your farm. (Circle all that apply)
   (a) Cow-calf segment (c) Stocker segment
   (b) Seedstock segment (d) Finishing segment

4. Approximately how many acres of land do you farm in total? ________ (acres)

5. How many acres of your farm were exclusively devoted to the **grass-fed beef cattle** operation in 2012, including pasture and other land that supports this operation? ________ (acres)

6. Please select any other farm enterprises that you were involved in last year. (Circle all that apply)
   (a) Dairy (d) Goats (g) Fruits and/or vegetables
   (b) Horses (e) Poultry (h) Forestry
   (c) Sheep (f) Field crops (i) Other livestock

## Section II. Breeding and Other Management Practices

1. Of the beef cattle you finished on grass in 2012, how many were from the following breed types?

| | | | |
|---|---|---|---|
| (a) British | _______ | (e) Cross British and Continental | _______ |
| (b) Continental | _______ | (f) Cross British and Brahman | _______ |
| (c) Brahman | _______ | (g) Cross Brahman and Continental | _______ |
| (d) Cross British, Continental, and Brahman | _______ | (h) Other (specify) ______________ | _______ |

2. Is there a specific breed or cross that comprises more than half of your total grass-fed beef herd?
   (a) Yes (b) No **[Please skip to 4.]**

3. If "**yes**" to 2 above, what is the breed or cross? ____________________________________________

4. Is your grass-fed beef enterprise certified organic? (a) Yes **[Please skip to 6.]** (b) No

5. If you answered "**No**" to (4), are you currently transitioning to certified organic? (a) Yes (b) No

6. Did you breed cows in 2011 to produce calves? (a) Yes (b) No **[Please skip to 9.]**

7. **[If Yes to 6]** What was your calving rate in 2012, measured in calves born per exposed cow? _______%

8. If you answered "**yes**" to (6), please indicate all reproductive management practices you use on your farm (Circle all that apply)
   (a) Artificial insemination (d) Sexed semen (g) Bull test
   (b) Embryo transfer (e) DNA marker-assisted selection (h) Defined breeding season
   (c) Breeding records (f) Pregnancy checking (i) Expected progeny differences

9. Which other animal management practices do you use? (Please select all that apply)
   (a) Vaccination (d) Body condition scoring (g) Regular vet consultation
   (b) Animal ID system (e) Insect control (h) Implanting
   (c) Deworming (f) Dehorning (i) Castration

10. Do your animals have access to shade (natural or artificial) during summer? (a) Yes (b) No
11. Do you test the quality of your forage? (a) Yes (b) No
12. Do you keep individual animal records? (a) Yes (b) No
13. Do you access the internet for grass-fed beef information? (a) Yes (b) No
14. Do you lock in beef input prices (animals, feeds, etc.) prior to purchasing (forward purchasing)? (a) Yes (b) No
15. Do you negotiate price discounts with dealers or suppliers of inputs? (a) Yes (b) No

**Section III. Selecting Animals for Grass Finishing**

Suppose you are selecting animals to bring into your herd to raise to slaughter/harvest weight. These could be either *purchased* or could have been *produced from your own cows (retained)*. **Animal A** and **Animal B** will represent hypothetical profiles of animals that could be brought into your herd for forage finishing. You will be asked to choose between these two animals based on the characteristics provided. Other than the characteristics provided, imagine that the animals are identical. If neither is acceptable, then "neither" option can be chosen.

Note:

***Weight*** refers to the weight in pounds (lbs) at which the animal is introduced to the forage-finishing phase.
***Body Frame*** refers to the animal's skeletal size based on its hip height (how big the animal is).
***Temperament*** refers to how easy or difficult the animal is to handle.
***Gender*** refers to whether the animal is a heifer, steer, or intact (non-castrated) male.
***Source*** refers to how you obtain the feeder animals for grass-finishing (retained from own cows, auctions, and/or private treaties).
***Color*** refers to the coat color of the animal, generalized as either black or non-black for this survey.
***Price*** represents the value of the animal per hundredweight (cwt). This could be the price paid to purchase the animal or the *market value of the retained animal* (produced from your cows).

**Choice 1**

| **Attributes** | **Animal A** | **Animal B** |
|---|---|---|
| Weight | 550 lbs | 650 lbs |
| Body frame | Small | Small |
| Temperament | Easy | Difficult |
| Gender | Heifer | Heifer |
| Source | Retained | Auction |
| Color | Non-black | Non-black |
| Price | $120/cwt | $160/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

2

**Choice 2**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 750 lbs | 650 lbs |
| Body frame | Small | Medium |
| Temperament | Difficult | Easy |
| Gender | Intact male | Intact male |
| Source | Auction | Auction |
| Color | Black | Non-black |
| Price | $140/cwt | $140/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 3**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 750 lbs | 750 lbs |
| Body frame | Medium | Medium |
| Temperament | Difficult | Difficult |
| Gender | Steer | Steer |
| Source | Private treaty | Auction |
| Color | Non-black | Black |
| Price | $160/cwt | $120/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 4**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 650 lbs | 550 lbs |
| Body frame | Medium | Large |
| Temperament | Easy | Easy |
| Gender | Heifer | Steer |
| Source | Retained | Private treaty |
| Color | Non-black | Non-black |
| Price | $120/cwt | $120/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 5**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 550 lbs | 550 lbs |
| Body frame | Medium | Small |
| Temperament | Easy | Difficult |
| Gender | Intact male | Heifer |
| Source | Private treaty | Private treaty |
| Color | Black | Black |
| Price | $140/cwt | $120/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 6**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 650 lbs | 750 lbs |
| Body frame | Small | Small |
| Temperament | Easy | Easy |
| Gender | Steer | Intact male |
| Source | Auction | Private treaty |
| Color | Non-black | Black |
| Price | $160/cwt | $160/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 7**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 750 lbs | 750 lbs |
| Body frame | Large | Large |
| Temperament | Difficult | Difficult |
| Gender | Steer | Intact male |
| Source | Auction | Retained |
| Color | Black | Non-black |
| Price | $140/cwt | $160/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 8**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 650 lbs | 650 lbs |
| Body frame | Large | Medium |
| Temperament | Difficult | Easy |
| Gender | Heifer | Heifer |
| Source | Retained | Retained |
| Color | Black | Non-black |
| Price | $120/cwt | $140/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

**Choice 9**

| Attributes | Animal A | Animal B |
|---|---|---|
| Weight | 550 lbs | 550 lbs |
| Body frame | Large | Large |
| Temperament | Easy | Difficult |
| Gender | Intact male | Steer |
| Source | Private treaty | Retained |
| Color | Black | Black |
| Price | $160/cwt | $140/cwt |

❖ Which animal would you retain/purchase for forage finishing if these were the only feeders available?

□ Animal A
□ Animal B
□ Neither

1. How important are each of the following attributes in your selection of grass-fed beef animals to produce on your farm? For each attribute, please circle the number that best represents your opinion.

| Attributes | Not Important at All | Somewhat Important | Very Important | Highly Important |
|---|---|---|---|---|
| Breed | 1 | 2 | 3 | 4 |
| Expected average daily weight gain | 1 | 2 | 3 | 4 |
| Frame score/body frame | 1 | 2 | 3 | 4 |
| Expected carcass yield | 1 | 2 | 3 | 4 |
| Disease resistance | 1 | 2 | 3 | 4 |
| Expected reproductive performance | 1 | 2 | 3 | 4 |
| Temperament | 1 | 2 | 3 | 4 |
| Heat tolerance | 1 | 2 | 3 | 4 |
| Hide/coat color of the animal | 1 | 2 | 3 | 4 |
| Parents of animals were never fed grain | 1 | 2 | 3 | 4 |

2. What is your main source of the feeder animals for grass-finishing?
(a) Calves from own cows (b) Buy from auctions (c) Private treaty (d) Other _______

**Section IV. Pasture and Grazing Management for the Grass-fed Beef Operation**

1. Please indicate the maximum number of animals and acres that were devoted to the following grazing systems in 2012.

| Number of Beef Animals | Acres | Grazing System |
|---|---|---|
| ___________ | _______ | *Rotational Grazing (RG)* is a management-intensive system of raising livestock on subdivided pastures called paddocks. Livestock are regularly rotated to fresh paddocks at the right time to prevent overgrazing and optimize grass growth. |
| ___________ | _______ | *Continuous Grazing (CG)* is a method of grazing livestock where animals have unrestricted and uninterrupted access to all pasture throughout the time period when grazing is allowed. |

2. Please list all the fields that supported the grass-fed beef enterprise on your farm in 2012. (There could have been more or less than 10 fields). Please indicate whether they were for hay, pasture or both, as shown in the three examples below.

| **Type** | **Description of Forage/ Hay** | **Purpose**<br>**Pasture only, hay only, or both** | **Number of Acres** |
|---|---|---|---|
| *Field Example 1* | *Bermudagrass in summer, ryegrass in winter* | *Both* | *20* |
| *Field Example 2* | *Orchardgrass year-round* | *Pasture* | *40* |
| *Field Example 3* | *Alfalfa* | *Hay* | *55* |
| Field 1 | | | |
| Field 2 | | | |
| Field 3 | | | |
| Field 4 | | | |
| Field 5 | | | |
| Field 6 | | | |
| Field 7 | | | |
| Field 8 | | | |
| Field 9 | | | |
| Field 10 | | | |

3. During the season(s) that you rotate animals, how often do you generally rotate them among pastures?
   (a) More than once per day
   (b) Every day or every other day
   (c) Once or twice a week
   (d) 1-3 times a month
   (e) 2-8 times a year

4. How do you believe the profitability associated with using a management-intensive rotational grazing (RG) system compares to that of using a continuous grazing system (CG) in your area?
   (a) RG lowers farm profit by > 20% relative to CG
   (b) RG lowers farm profit by 1-20% relative to CG
   (c) RG does not change farm profit relative to CG
   (d) RG increases farm profit by 1-20% relative to CG
   (e) RG increases farm profit by >20% relative to CG

5. If you produced hay from pasture in 2012, how many bales of hay did you produce? _____ bales of weight ____lbs each

6. Of the total hay produced, what percentage did you sell?
   (a) None
   (b) 1-20%
   (c) 21-40%
   (d) 41-60%
   (e) 61-80%
   (f) 81-99%
   (g) All hay was sold

7. If you purchased hay to feed animals, how many bales did you purchase in 2012? ______ bales of weight ____lbs each

### Section V. Reasons for Selecting the Grass-fed Beef Enterprise

1. To what extent do you agree or disagree that your **selection of a grass-fed beef enterprise as opposed to other potential farm enterprises** is because of the following reasons? Please rate each reason on the scale provided below.

| Reason | Strongly Agree | Somewhat Agree | Neutral | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| Grass-fed beef production is profitable | 1 | 2 | 3 | 4 | 5 |
| Producing grass-fed beef is low-cost | 1 | 2 | 3 | 4 | 5 |
| I want to produce healthy beef | 1 | 2 | 3 | 4 | 5 |
| Producing grass-fed beef is enjoyable | 1 | 2 | 3 | 4 | 5 |
| I have ample land suitable for grazing | 1 | 2 | 3 | 4 | 5 |
| Producing grass-fed beef is good for the environment | 1 | 2 | 3 | 4 | 5 |
| There is strong demand for grass-fed beef in my area | 1 | 2 | 3 | 4 | 5 |
| Raising grass-fed beef is a good activity for my family | 1 | 2 | 3 | 4 | 5 |
| Grass-fed beef systems are more sustainable than grain-fed beef systems | 1 | 2 | 3 | 4 | 5 |

2. Do any other family members work on your grass-fed beef farm? (a) Yes (b) No **[Please skip to 4.]**

3. If you answered "**yes**" to (2), how many total hours do other family members (besides you) work on your grass-fed beef operation per week?
   (a) 1-10 hrs (c) 21-30 hrs (e) 41-50 hrs
   (b) 11-20 hrs (d) 31-40 hrs (f) > 50 hrs

4. Do you use hired labor on your grass-fed beef operation? (a) Yes (b) No

5. Do any of your children or other family members plan to take over your farm operation upon your retirement?
   (a) Yes (b) No

6. Do you plan to expand or reduce your grass-fed beef herd size in the next 12 months? Please check the one that applies.
   (a) Yes, I will expand my herd by > 30%
   (b) Yes, I will expand my herd by 16-30%
   (c) Yes, I will expand my herd by 1-15%
   (d) No, I will keep the same number of cattle
   (e) No, I will reduce my herd by 1-15%
   (f) No, I will reduce my herd by 16-30%
   (g) No, I will reduce my herd by > 30%

7. Which of the following terms would apply to the grass-fed beef produced by animals on your farms? (Circle all that apply.
   (a) Natural (c) Hormone-free (e) Lean
   (b) Antibiotic-free (d) Local (f) Tender

**Section VI. Goal Structure of Grass-fed Beef Producers**

1. Grass-fed beef producers may have a number of goals with respect to their operations. Below are some potential goals that you may have for your farm operation. Some goals are likely to be more important to you than others. In this section, **you will be asked to compare each of eight goals with each of the other goals**. We are interested in how important each goal is to you when compared to the other goals. Questions will be worded in a similar manner to the one in the following example.

> Example: Assume you are asked to compare two goals, **maximize profit** and **produce healthy beef**. If the goal **maximize profit** is much more important to you than the goal **produce healthy beef**, then you would place an "**X**" very near the goal **maximize profit**, as shown below
>
> Maximize profit --**X**------------------------I---------------------------- Produce healthy beef.
>
> On the other hand, if the goal **produce healthy beef** is slightly more important to you than the goal **maximize profit**, then you would place an "**X**" nearer to the goal **produce healthy beef**, but close to the middle, as shown:
>
> Maximize profit ----------------------------I--**X**------------------------ Produce healthy beef.
>
> If both goals are equally important, you would place an "**X**" at the middle of the line.
>
> Maximize profit ----------------------------**X**---------------------------- Produce healthy beef.
>
> *Where the "X" is marked on the line will indicate how much more important one goal is than the other.*

7

As shown above, please indicate your preferences for each of the following goals by placing an "X" **at the point on the line that best represents your preferences** for each comparison.

Maximize profit -------------------------I------------------------ Produce healthy beef
Maximize profit -------------------------I------------------------ Maintain and conserve land
Maximize profit -------------------------I------------------------ Increase farm size
Maximize profit -------------------------I------------------------ Increase net worth
Maximize profit -------------------------I------------------------ Avoid years of loss/low profit
Maximize profit -------------------------I------------------------ Have time for other activities
Maximize profit -------------------------I------------------------ Have family involved in agriculture
Produce healthy beef -------------------------I------------------------ Maintain and conserve land
Produce healthy beef -------------------------I------------------------ Increase farm size
Produce healthy beef -------------------------I------------------------ Increase net worth
Produce healthy beef -------------------------I------------------------ Avoid years of loss/low profit
Produce healthy beef -------------------------I------------------------ Have time for other activities
Produce healthy beef -------------------------I------------------------ Have family involved in agriculture
Maintain and conserve land -------------------------I------------------------ Increase farm size
Maintain and conserve land -------------------------I------------------------ Increase net worth
Maintain and conserve land -------------------------I------------------------ Avoid years of loss/low profit
Maintain and conserve land -------------------------I------------------------ Have time for other activities
Maintain and conserve land -------------------------I------------------------ Have family involved in agriculture
Increase farm size -------------------------I------------------------ Increase net worth
Increase farm size -------------------------I------------------------ Avoid years of loss/low profit
Increase farm size -------------------------I------------------------ Have time for other activities
Increase farm size -------------------------I------------------------ Have family involved in agriculture
Increase net worth -------------------------I------------------------ Avoid years of loss/low profit
Increase net worth -------------------------I------------------------ Have time for other activities
Increase net worth -------------------------I------------------------ Have family involved in agriculture
Avoid years of loss/low profit -------------------------I------------------------ Have time for other activities
Avoid years of loss/low profit -------------------------I------------------------ Have family involved in agriculture
Have time for other activities -------------------------I------------------------ Have family involved in agriculture

### Section VII. Marketing

1. How important are the following factors in your decision of when to harvest or sell your cattle?

| Factors | Not Important at all | Somewhat Important | Very Important | Highly Important |
|---|---|---|---|---|
| Market price | 1 | 2 | 3 | 4 |
| Immediate need for cash | 1 | 2 | 3 | 4 |
| Age of the animal | 1 | 2 | 3 | 4 |
| Weight of the animal | 1 | 2 | 3 | 4 |
| Body frame | 1 | 2 | 3 | 4 |
| Availability of forages (hay/pasture) | 1 | 2 | 3 | 4 |
| Consumer demand | 1 | 2 | 3 | 4 |
| Time of the year | 1 | 2 | 3 | 4 |

2. At what average live weight are your grass-fed beef animals ready for harvest/slaughter? ______ (lbs)

3. How many grass-fed beef animals were raised to slaughter weight on your farm in 2012? ______ (number)

4. Did you sell grass-fed beef as meat in 2012? (a) Yes **[Please continue with 5]** (b) No **[skip to section VIII.]**

5. **[If yes to 4]**, in which form was the beef sold? (Circle all that apply)
   (a) Whole carcass
   (b) Whole side
   (c) Quarter
   (d) Mixed quarter
   (e) Box - different sized
   (f) Individual cut
   (g) Hamburger
   (h) Other

6. Do you sell your beef seasonally or year-round? (Please circle one) (a) Seasonally (b) Year-round

7. How do you advertise your beef product?
   (a) Word-of-mouth
   (b) Radio and/or TV
   (c) Newspaper or magazine
   (d) Internet
   (e) Email
   (f) Direct mail
   (g) Telephone
   (h) I do not advertise
   (i) Other _____

8. What are your primary sources of information for market prices for grass-fed beef? (Circle all that apply)
   (a) Other farmers
   (b) Extension service
   (c) Farm organizations
   (d) TV, radio or magazines
   (e) Internet
   (f) Other _________

9. Which of the following marketing channels do you use to sell your beef? (Please circle all that apply)
   (a) Direct sale to consumers
   (b) Online/internet
   (c) Cooperative
   (d) Restaurant
   (e) Grocery stores
   (f) Farmer's Market
   (g) Wholesalers and/or retailers
   (h) Dealers, brokers or meat packers

**Section VIII. Important Challenges Currently Facing Grass-Fed Beef Producers**

1. To what extent do you agree or disagree that the following challenges are having significant negative impacts on grass-fed beef producers in your area? Please select a number in each category based on the headings provided.

| Challenges | Strongly Agree | Somewhat Agree | Neutral | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| High cost of grass-fed beef production | 1 | 2 | 3 | 4 | 5 |
| Lack of a clear marketing system for grass-fed beef | 1 | 2 | 3 | 4 | 5 |
| Strong market competition from feedlot beef | 1 | 2 | 3 | 4 | 5 |
| Lack of steady demand for grass-fed beef | 1 | 2 | 3 | 4 | 5 |
| Pasture management problems | 1 | 2 | 3 | 4 | 5 |
| Limited land available for grazing | 1 | 2 | 3 | 4 | 5 |
| Diseases | 1 | 2 | 3 | 4 | 5 |
| Long period of time required to get animals to slaughter weight | 1 | 2 | 3 | 4 | 5 |
| Shortage of processors close by that will handle grass-fed beef | 1 | 2 | 3 | 4 | 5 |
| Grass-fed beef production is labor intensive relative to cow-calf production | 1 | 2 | 3 | 4 | 5 |
| Transportation and distribution problems for grass-fed beef | 1 | 2 | 3 | 4 | 5 |

**Section IX. Demographic and Financial Information**

1. What is your gender? (Circle one) (a) Male (b) Female

2. Which of the following best describes your ethnic background? (Circle one)
   (a) American Indian (c) Black (African American) (e) White (Caucasian)
   (b) Asian or Pacific Islander (d) Hispanic/Latino (f) Other _________

3. Please indicate your age. (Circle one)
   (a) ≤30 years (b) 31-45 years (c) 46-60 years (d) 61-75 years (e) ≥76 years

4. Please indicate your highest level of education. (Circle one)
   (a) Less than high school (c) Technical college (e) Advanced degree (M.D., DVM. M.S., Ph.D., etc.)
   (b) High school diploma/GED (d) Bachelor's degree

5. What is your debt-to-asset ratio? (100*total debts / total assets).
   (a) 0-30% (b) 31-60% (c) > 60%

6. Do you have an off farm job?
   (a) Yes (b) No **[skip to 8]**

7. **[If yes to 6]** How many hours per week do you work off the farm? ____ (hours per week)

8. Which of the following best describes your 2012 annual **net household income** from **all sources**?
   (a) < $50,000 (b) $50,000-$100,000 (c) > $100,000

9. Approximately what percentage of your **net household income** comes from **off-farm sources**? (Circle one)
   (a) 0 to 19% (c) 40 to 59% (e) 80 to 100%
   (b) 20 to 39% (d) 60 to 79%

10. What percentage of your annual **net farm income** comes from your grass-fed beef operation? (Circle one)
    (a) 0-19% (b) 20-39% (c) 40-59% (d) 60-79% (e) 80-100%

11. Relative to other investors, how would you characterize yourself? (Please check one).
    (a) I tend to take on substantial levels of risk in my investment decisions
    (b) I neither seek nor avoid risk in my investment decisions.
    (c) I tend to avoid risk when possible in my investment decisions.

***Within the next few months, we will be sending a follow-up survey on production costs to those who indicate they are willing to participate. This will allow us to analyze industry profitability. We would greatly appreciate your participation in that survey. Would you be willing to participate in that 4-page survey?***
***(a) Yes*** ***(b) No***

**THANK YOU FOR YOUR PARTICIPATION IN THIS SURVEY!**

## Appendix B: Institutional Review Board Approval for the First Survey

LSU AgCenter Research & Extension
LSU AgCenter Institutional Review Board (IRB)
Dr. Michael J. Keenan, Chair
School of Human Ecology
209 Knapp Hall
225-578-1708
mkeenan@agctr.lsu.edu

**Application for Exemption from Institutional Oversight**

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

- Applicant, please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the LSU AgCenter IRB. Once the application is completed, please submit the original and one copy to the chair, Dr. Michael J. Keenan, in 209 Knapp Hall.

- A Complete Application Includes All of the Following:
  **(A)** The original and a copy of this completed form and a copy of parts B through E.
  **(B)** A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  **(C)** Copies of all instruments and all recruitment material to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal.
  **(D)** The consent form you will use in the study (see part 3 for more information)
  **(E)** Beginning January 1, 2009: Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing and handling data, unless already on file with the LSU AgCenter IRB.
  Training link: (http://grants.nih.gov/grants/policy/hs/training.htm)

**1) Principal Investigator: Jeffrey Gillespie Rank: Professor Student?** No
**Dept: Agricultural Economics & Agribusiness Ph: 225-578-2759 E-mail: jmgille@lsu.edu**
**2) Co-Investigator(s):** please include department, rank, phone and e-mail for each
- If student as principal or co-investigator(s), please identify and name supervising professor in this space

Ph.D. Students Isaac Sitienei and Basu Bhandari will be assisting in this, but I am the principal investigator.

**3) Project Title: U.S. Grass-fed Beef Production Survey**
**4) Grant Proposal?(yes or no) No If Yes, Proposal Number and funding Agency N/A**
Also, if Yes, either: **this application completely matches the scope of work in the grant Y/N__**
**OR**
**more IRB applications will be filed later Y/N___**
**5) Subject pool (e.g. Nutrition Students) Grass-fed Beef Farmers**
- Circle any **"vulnerable populations" to be used:** (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

**6) PI signature** ______ ****Date** 6/27/13 (no per signatures)
****I certify that my responses are accurate and complete.** If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

**Committee Action:** Exempted √ Not Exempted____ **IRB#** HE13-8
**Reviewer** Michael Keenan **Signature** Michael Keenan **Date** 7-15-2013

**Appendix C: The Second Survey**

# U.S. Grass-fed Beef Production Cost and Returns Survey

LSU AgCenter Research & Extension

**Throughout this survey, you will be asked questions about your farm production returns and expenses for 2012. Please provide as accurate information to the questions as possible. It is important for the results to truly represent your farm. All information will be kept *<u>strictly confidential</u>*. This is a condition of the grant funding for this project and the Louisiana State University Agricultural Center's Internal Review Board. Thank You!**

**SALES**

1. After subtracting marketing expenses, what was the **total dollar value** this operation received in 2012 for each of the following crop and/or livestock commodities?

| | ***Dollars*** |
|---|---|
| A. All crops excluding hay (field crops, vegetables, floriculture, Christmas trees, greenhouse, nursery, shrubbery, sod and silage, etc.)………………… …………………....................... | $_____ |
| B. Hay ……..………………………………...…………................................................................. | $_____ |
| C. Approximately what percentage of the hay sold was made from pastures devoted to grass-fed beef production?……….……………… ………..………………………………………….. | $_____ |
| D. Animal and animal products other than grass-fed beef animals including honey bees...……… | $_____ |
| F. Grass-fed beef meat………………………………..………………………………………...…….. | $_____ |
| G. Grass-fed beef heifers and steers………………………………………………………………… | $_____ |

**MARKETING CHARGES**

2. In 2012, how much was spent by this operation (operators, partners, landlords, and contractors) for marketing and storage expenses? (*Include check-off, commissions, storage, inspection, ginnings, etc.; and marketing expenses for contract sales.*)………………......................................... $_____

   A. How much of this (*item 2*) was for the grass-fed beef enterprise? ......................................... $_____

**OPERATING EXPENSES**

3. For this operation in 2012, how much was spent for each of the following items?

   A. Seeds, sets, plants, seed cleaning and treatments, transplants, trees, and nursery stock? (*Include technology or other fees, seed treatments, and seed cleaning costs.*)………............ $_____
      a. How much of this (*item A*) was for the grass-fed beef enterprise?...................................... $_____

   B. Nutrients, fertilizer, lime, and soil conditioners? (*Include cost of custom application and organic materials.*) ……………………………………………………………………………….. $_____
      a. How much of this (*item B*) was for pasture management for grass-fed beef production?.... $_____

   C. Bio-controls and agricultural chemicals for crops, livestock, poultry, and general farm use? (*Include pest controls and custom application costs.*)………………………………………… $_____
      a. How much of this (*item C*) was for pasture management for grass-fed beef production?.... $_____

D. Livestock purchases of:
   a. Weaned calves purchased for grass-fed beef finishing?........................................................ $_____
   b. Other beef and dairy cattle, hogs, pigs, sheep, goats, chicken, turkeys, lambs, bees, brooder fish, fingerlings, etc.?...................................................................................... $_____

E. Purchased feed, hay, and silage for livestock, dairy, poultry, and/or aquaculture?.................. $_____
   a. How much of this (*item E*) was for the grass-fed beef enterprise? ..................................... $_____

F. Bedding and litter for livestock? ...................................................................................... $_____
   a. How much of this (*item F*) was for the grass-fed beef enterprise? ..................................... $_____

G. Medical supplies, veterinary, and custom services for livestock? (*Include artificial insemination, branding, breeding fees, caponizing, castrating, custom feed processing, hormone injections, performance testing, pregnancy testing, seining, sheep shearing, medicine, etc.*)........................................................................................ $_____
   a. How much of this (*item G*) was for the grass-fed beef enterprise? ..................................... $_____

H. All fuels, oils, and lubricants? (*Include diesel fuel, gasoline and gasohol, natural gas, LP gas, oils and lubricants, and all other fuel.*)..................................................... $_____
   a. How much of this (*item H*) was for the grass-fed beef enterprise? ..................................... $_____

I. Electricity, all other utilities and water for irrigation? (*Include the farm share of telephone service, water purchased for irrigation or otherwise, internet access,etc.*)............................ $_____
   a. How much of this (*item I)* was for the grass-fed beef enterprise? ....................................... $_____

J. Farm supplies, marketing containers, hand tools, and farm shop power equipment? (*Include expenses for temporary fencing. Exclude expenses for bedding / litter and permanent fencing.*)......................................................................................................................... $_____
   a. How much of this (*item J*) was for the grass-fed beef enterprise? ....................................... $_____

K. Repairs, parts, and accessories for motor vehicles, machinery, and farm equipment? (*Include drying equipment, tune-ups, overhauls, repairs to livestock equipment, replacement parts for machinery, tubes, tires, and accessories such as air conditioners, CB's, radios, and hydraulic cylinders. Exclude irrigation equipment and pump repairs.*)................................................. $_____

L. Maintenance and repair for the upkeep of all farm buildings, land improvements, and all other farm/ranch improvements? (*Include conservation improvements, corrals, feeding floors, feedlots, gravel, land drainage structures, tiling, trench, silos, wells, irrigation equipment and pump repairs and facilities. Exclude any new construction or remodeling.*).................. $_____
   a. How much of this (*item L* ) was for the grass-fed beef enterprise? ..................................... $_____

M. Insurance for the farm business? (*Include all casualty insurance, hail insurance, and any other crop of livestock insurance; motor vehicle liability and blanket insurance policies.*)..... $_____

N. Interest and fees paid on debts for the operation? ........................................................................ $_____
a. How much of this (*item N)* was for the grass-fed beef enterprise? .......................................... $_____

O. Property taxes paid on farm real estate (land and buildings), livestock, machinery, and other farm production items?............................................................................................................... $_____

P. Renting or leasing of tractors, balers, rakes, farm vehicles, equipment, or storage structures?.. $_____
a. How much of this (*item P*) was for the grass-fed beef enterprise? ......................................... $_____

Q. Renting or leasing of land for the farm operation? ................................................... $_____
a. How much of this (*item Q*) was for the grass-fed beef enterprise?................................ $_____

R. Farm vehicle and licensing fees? ....................................................................................... $_____

S. Depreciation expense claimed by this operation in 2012 for all capital assets? ....................... $_____

T. Cash wages paid to hired farm and ranch labor plus payroll taxes and benefits? (*Include cash wages, incentives and bonuses, payments to corporate officers and paid family members including yourself and other operators if they received a wage. Also include expenses for contract labor. Employer's share of Social Security and unemployment taxes; employer's share of health insurance, pension or retirement plans, Workers Compensation, etc.*)........... $_____
a. How much of this (*item T*) was for the grass-fed beef enterprise? ....................................... $_____

U. Custom work, performed by machines and labor hired as a unit? (*Include custom grain, livestock, milk, manure, and other custom hauling; and all other custom work including machine hire and machinery and equipment rental.*)................. ............................... $_____

V. What was the cash value of feed, farm commodities, fuel, housing, meals, other food, utilities, vehicles for personal use, and other non-cash payment for farm work?...................... $_____

W. Professional or farm management services such as record-keeping, accounting, tax and business planning, farm product advice, conservation practices, etc.?...................................... $_____

**Thank you for your participation in the survey!**

**Appendix D: Institutional Review Board Approval for the Second Survey**

LSU AgCenter Institutional Review Board (IRB)
Dr. Michael J. Keenan, Chair
School of Human Ecology
209 Knapp Hall
225-578-1708
mkeenan@agctr.lsu.edu

Application for Exemption from Institutional Oversight

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

- Applicant, please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the LSU AgCenter IRB. Once the application is completed, please submit the original and one copy to the chair, Dr. Michael J. Keenan, in 209 Knapp Hall.

- A Complete Application Includes All of the Following:
  **(A)** The original and a copy of this completed form and a copy of parts B through E.
  **(B)** A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  **(C)** Copies of all instruments and all recruitment material to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal.
  **(D)** The consent form you will use in the study (see part 3 for more information)
  **(E)** Beginning January 1, 2009: Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing and handling data, unless already on file with the LSU AgCenter IRB.
  Training link: (http://grants.nih.gov/grants/policy/hs/training.htm)

**1) Principal Investigator: Jeffrey Gillespie** **Rank: Professor** **Student?** No
**Dept: Ag Econ & Agribusiness** **Ph: 578-5729** **E-mail: jmgille@lsu.edu**
**2) Co-Investigator(s):** please include department, rank, phone and e-mail for each
- If student as principal or co-investigator(s), please identify and name supervising professor in this space

**3) Project Title: Survey to Estimate Costs and Returns of U.S. Grass-fed Beef Production**

**4) Grant Proposal?(yes or no) No. If Yes, Proposal Number and funding Agency**______________
Also, if Yes, either: **this application completely matches the scope of work in the grant Y/N**__
**OR**
**more IRB applications will be filed later Y/N**___

**5) Subject pool (e.g. Nutrition Students): Grass-fed Beef Farmers**
- Circle any **"vulnerable populations" to be used:** (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

**6) PI signature**______________ ****Date** 10/14/13 (no per signatures)
****I certify that my responses are accurate and complete.** If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

**Committee Action:** Exempted √ Not Exempted____ **IRB#** HE13-16

**Reviewer** Michael Keenan **Signature** Michael Keenan **Date** 10-23-2013

## Appendix E. Open Access Agreement

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**Journal of Agricultural and Applied Economics** **AAE**

In consideration of the publication in **Journal of Agricultural and Applied Economics** of the contribution entitled:
ANALYSIS OF PASTURE SYSTEMS TO MAXIMIZE THE PROFITABILITY AND SUSTAINABILITY OF GRASS-FED BEEF PRODUCTION
by (all authors' names): BASU BHANDARI, JEFFREY GILLESPIE, GUILLERMO SCAGLIA, JIM WANG, MICHAEL SALASSI

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**Appendix F. Specific Gravity and Active Ingredient of Pesticides**

| Pesticides | Specific Gravity | Active Ingredient | Percentage Active Ingredient |
|---|---|---|---|
| Roundup Original | 1.36 | Glyphosate | 49 |
| Grazon P+D | 1.143 | 2,4-D + Picloram | 39.6+10.2 |
| Gramoxone | 1.13 | Paraquat | 43.8 |
| Outrider | 1.55 | Sulfosulfuran | 75 |
| Platoon | 1.161 | Dimethylamine salt of 2,4-D | 47.3 |
| Malathion 57EC | 1.0768 | Malathion | 57 |
| Sevin 80WP | - | Carbaryl | 80 |

Note: Specific gravity and percentage of active ingredient contained in pesticides are as per the material safety data sheets of the respective pesticides.

## VITA

Basu Deb Bhandari was born in the remote village Gulmi district of Nepal where he grew up his childhood and earned high school diploma (School Leaving Certificate) from Himalayan Higher Secondary School, Bastu-5, Gulmi. He then joined to Institute of Agricultural and Animal Science, Rampur, Chitwan, Nepal under the Tribhuwan University and completed his undergraduate degree in Agriculture.

He then joined as a technical research officer in the Nepal Agricultural Research Council. Within one year and 3 months, he joined the Department of Agriculture as a plant protection officer. In the meantime, he visited different countries such as the Netherlands, Indonesia, and Japan to evaluate different agricultural programs and to acquire training in different agricultural activities. He received the competitive Indian Aid Fund Scheme award to earn his master of agricultural science in agricultural entomology from Mahatma Phule Krishi Vidya Peeth, Rahuri, Ahmednagar district, Maharashtra India. He was awarded with Hexamer Foundation Gold Medal being the rank one student in his discipline in 2001. Again he resumed his position in the Department of Agriculture with higher responsibilities. He was promoted to senior plant protection officer in 2009 and served for a year before he moved to United States in 2010 to earn his higher degrees.

He joined the Department of Agricultural Economics and Agribusiness in 2011. He was awarded with an outstanding MS student in 2012 in the Department of Agricultural Economics and Agribusiness and completed his Master of Science in Agricultural Economics in May, 2013. He published peer reviewed and extension articles and now he is a doctoral candidate scheduled to graduate in August 2015.